

A microscopic view of a pipette tip. The tip is filled with a red liquid containing numerous small, bright red particles. The background is a blurred gradient of blue and purple. The numbers '800' and '600' are visible on the pipette's scale, along with the text '± 0.08 ml'.

AMERICAN CHEMICAL SOCIETY

Chemical Safety Manual for Small Businesses

THIRD EDITION

EMERGENCY TELEPHONE NUMBERS

(Fill in missing numbers.)

Fire Department _____

Ambulance _____

Physician or Nurse _____

Police _____

Poison Control Center _____

Security Office _____

Supervisor work: _____

home: _____

Useful websites:

American Chemical Society

www.chemistry.org

American Conference of Governmental Industrial Hygienists

www.acgih.org

American Industrial Hygiene Association

www.aiha.org

Compressed Gas Association

www.cganet.com

National Institute for Occupational Safety and Health

www.cdc.gov/niosh

Occupational Safety & Health Administration

www.osha.gov

U.S. Department of Energy

www.energy.gov

U.S. Environmental Protection Agency

www.epa.gov

U.S. Small Business Administration

www.sba.gov

The Small Business Act (SBA) was established to aid, counsel, assist, and protect the interests of small business concerns; to preserve free competitive enterprise; to insure that a fair portion of total purchases by the government is placed with small business enterprises; and to maintain and strengthen the overall economy of the nation. SBA also defines a small business concern as "one that is independently owned and operated and which is not dominant in its field of operation." Finally, the act also states that in determining what is a small business, the definition shall vary from industry to industry to the extent necessary to properly reflect industry differences.

Chemical Safety Manual for Small Businesses

GUIDES FOR MANAGERS, ADMINISTRATORS, AND EMPLOYEES

Third Edition

A Publication of the American Chemical Society
Committee on Chemical Safety
and
Division of Small Chemical Businesses

PREFACE

During the fourteen years since the publication of the second edition, several new topics have developed that are relevant to small businesses. The Occupational Safety & Health Administration's Laboratory Standard and its resulting Chemical Hygiene Plan are a regular part of every laboratory in the United States. The science of ergonomics continues to evolve, as do strategies for improving workstations and equipment. Safety professionals need to be skilled in conducting exposure assessments. Laboratories and manufacturing areas must be designed to accommodate qualified persons who may have a disability. The Internet provides access to a wealth of safety information, although sources must be evaluated for reliability. Plant and laboratory security must be assured. The Division of Chemical Health and Safety of the American Chemical Society (ACS) now publishes the *Journal of Chemical Health & Safety* to keep chemists and safety professionals aware of the best practices and latest developments in chemical safety. All division members receive this journal as a benefit of membership.

The *Chemical Safety Manual for Small Businesses* serves as only a brief outline of the most basic guidelines in chemical safety. Appendix I contains many recommended sources of additional information that is supplementary to the contents of this booklet. Small businesses have a continuing challenge to keep up with new regulations while protecting employees and maintaining efficient operations.

I am pleased to introduce the third edition of this important communication of the ACS Committee on Chemical Safety (CCS). The committee wishes to thank the many individuals who generously contributed their time and wisdom to this and the previous editions. Their efforts have helped to make small businesses that make or use chemicals safer places with fewer accidents and injuries. Jay Young has contributed to most of the CCS publications, including both earlier editions of this booklet; his influence continues to touch our readers. Eileen Segal updated the appendices and several sections of the text. Erik Talley suggested several new topics and drafted the resulting sections. Other reviewers included Barbara Foster, Russ Phifer, Harry Elston, Wayne Wolsey, Doug Walters, Kevin Edgar, Dan McDonald, Pat Redden, Art Marcinkowsky, Cherlyn Bradley, Paul Schickedantz, and Al Hazari. Bob Gates and Jim Landis contributed the perspective of the ACS Committee on Chemists with Disabilities. Both Larry Funke and Bob Rich coordinated the efforts of those ACS staff members involved in the production and distribution activities.

All comments are welcome. Please direct them to the Committee on Chemical Safety, American Chemical Society, 1155 Sixteenth Street, NW, Washington, DC 20036.

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Past Chair (2002-2004), ACS
Committee on Chemical Safety
January 2006

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PREFACE TO THE FIRST EDITION

Safety in the use of chemicals has become the theme of a great deal of public concern and legislative activity. Recent federal, state, and local legislation has included many small businesses in hazardous materials management regulations. The American Chemical Society Committee on Chemical Safety has developed this manual for all of those who work with chemicals and particularly for small businesses that may not have specialized expertise in chemical safety. This manual will be of broad benefit to chemists and non-chemists alike.

Information presented in the manual is of two types: i) suggestions for working safely following generally accepted practices, and ii) specific regulations resulting from legislative actions. The first pages of text are directed to management; they relate mainly to philosophy, facilities, practices, and policies. The remainder of the manual is directed to employees and may be interpreted or modified to fit particular requirements.

This is not a text or a "cookbook", but a point of departure for responsible actions when chemicals are handled. Safety is affirmative action, based on awareness of personal responsibilities, on knowledge of the hazards and other properties of materials, and on a constructive attitude in the application of that awareness and knowledge.

Completion of this manual resulted from the dedicated efforts of members and friends of the Committee on Chemical Safety who read and critiqued the early manuscripts. Lyle Phifer initiated the project and served as the subcommittee chairman. He was enthusiastically supported in the writing effort by Leonard Gray, Kenneth Greenlee, Ellen Mimnaugh, and Jay Young. Maureen Matkovich, the committee liaison, provided invaluable technical assistance. Earl Peters, Stanley Pine, and Maureen Matkovich proofread the final manuscript. The American Chemical Society Divisions of Chemical Health and Safety and of Small Chemical Businesses endorsed the manual, and the Corporation Associates provided a grant in partial support of the project.

All comments are welcome. Please direct them to the Committee on Chemical Safety, American Chemical Society, 1155 Sixteenth Street, NW, Washington, DC 20036.

Stanley H. Pine
Chairman, ACS Committee on
Chemical Safety
[October 1988]

DISCLAIMER

The materials contained in this manual have been compiled by recognized authorities from sources believed to be reliable and to represent the best opinions on the subject. This manual is intended to serve only as a starting point for good practices and does not purport to specify minimal legal standards or to represent the policy of the American Chemical Society. No warranty, guarantee, or representation is made by the American Chemical Society as to the accuracy or sufficiency of the information contained herein, and the society assumes no responsibility in connection therewith. This manual is intended to provide basic guidelines for safe practices. Therefore, it cannot be assumed that all necessary warning and precautionary measures are contained in this document and that other or additional information or measures may not be required. Users of this manual should consult pertinent local, state, and federal laws and legal counsel prior to initiating any safety program.

LIST OF ABBREVIATIONS AND ACRONYMS

ac - alternating current
ACGIH - American Conference of Governmental Industrial Hygienists
ACS - American Chemical Society
ADA - Americans with Disabilities Act
AEDs - automatic external defibrillators
ALARA - as low as reasonably achievable
ANSI - American National Standards Institute
ASHRAE - American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BHT - 2,6-ditertiary-4-methylphenol
CAS - Chemical Abstracts Service
CCS - ACS Committee on Chemical Safety
CD-ROM - compact disc read-only memory
CEO - chief executive officer
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
CFR - Code of Federal Regulations
CPR - cardiopulmonary resuscitation
CWD - ACS Committee on Chemists with Disabilities
DART/ETIC - Developmental and Reproductive Toxicology/Environmental Teratology Information Center
dc - direct current
DHHS - Department of Health and Human Services
DOT - Department of Transportation
EEOC - Equal Employment Opportunity Commission
EPA - Environmental Protection Agency
IUPAC - International Union of Pure and Applied Chemistry
MSDS - material safety data sheet
NaK - sodium-potassium alloys
NEC - National Electrical Code
NFPA - National Fire Protection Association
NIOSH - National Institute for Occupational Safety and Health
OSHA - Occupational Safety & Health Administration
PEL - Permissible Exposure Limit
RCRA - Resource Conservation and Recovery Act
SARA - Superfund Amendments and Reauthorization Act
SBA - Small Business Act
TBC - 4-tertiary-butylcatechol
TCLP - Toxicity Characteristic Leaching Procedure
THF - tetrahydrofuran
TLC - thin-layer chromatography
TLV - Threshold Limit Value
TOXNET - National Library of Medicine Toxicology Data Network
TSDF - treatment, storage, or disposal facility
UV - ultraviolet
WEEL - workplace environmental exposure level

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PART I

**Guide for
Managers and
Administrators**

1. INTRODUCTION

The American Chemical Society (ACS) Committee on Chemical Safety (CCS) has prepared these guidelines for prudent practice in small businesses. However, the guidelines can be adapted to practices in all operations using chemicals, including large research, clinical, quality control, and development laboratories. These general recommendations can serve as a basis for more detailed instructions prepared for each chemical facility by those directly responsible for the operation of that facility.

There is a preferred way to perform all work with chemicals that can both reduce the probability of an accident to a negligible level and minimize its consequences, should one occur. Risk minimization depends on safe work practices; the use of personal protective equipment; appropriate engineering controls; and, when possible, the substitution of a less hazardous chemical for a more hazardous one. A question to ask before beginning an operation or performing an experiment is, "What would happen if...?" Answers to this question require an understanding of the hazards associated with the chemicals and equipment involved. The reactivity, flammability, corrosiveness, and toxicity of chemicals used will dictate the precautions to be taken. Such information might well form an introductory section to all written procedures.

An effective and mandatory safety program will have strong support from the chief executive officer (CEO) and will have the active participation of all employees. Without the enthusiastic support of the CEO, who is ultimately responsible for safety within any facility, an effective safety program is rarely achieved. An appropriately trained and qualified safety officer is essential. Laboratories meeting the criteria in the Occupational Safety & Health Administration's (OSHA's) Laboratory Standard are required to have a designated chemical hygiene officer. However, even the best safety coordinator cannot relieve the CEO, the administrative and technical staff, and each employee of the responsibility for the safety of operations under their jurisdiction. A good safety program includes constant training and reminders of the common hazards that workers may face and attention to the equipment and facilities that workers use.

Good practice requires mandatory safety rules. The following are recommended parts of a program that establishes safe conditions for the employees:

- a. Regular safety inspections at intervals of no more than 3 months (and at shorter intervals for certain types of equipment, such as eyewash fountains)
- b. Procedures that ensure proper disposal of waste chemicals at regular intervals
- c. Formal and regular safety training that ensures that a sufficient number of full-time personnel are knowledgeable in the proper use of emergency equipment and procedures
- d. Regular monitoring of the performance of ventilation systems

2. RESPONSIBILITY FOR SAFETY

The CEO, line organization, and staff are responsible for the administration of the safety program. Each individual is responsible for performing his or her job safely following an appropriate training program. Untrained technicians, operators, or visitors should not be permitted to work with laboratory or plant chemicals.

Every supervisor should do the following:

- a. Set a good example by
 - observing all rules and recommendations,
 - wearing protective equipment where recommended, and
 - being enthusiastic about safety.
- b. Be alert for unsafe conditions.
- c. Conduct frequent and thorough inspections.
- d. Take effective corrective action promptly.
- e. Maintain discipline and enforce rules.
- f. Assume responsibility for visitors and require that they follow the same rules as the employees and are escorted or supervised at all times.
- g. Carefully review all procedures for possible health, safety, and environmental concerns before the work is begun. Provide training to ensure that workers can perform each task safely.
- h. Maintain a file of publications on chemical safety that is readily available to employees, visitors, and others, and encourage its use.
- i. Obtain or generate a material safety data sheet (MSDS) for each chemical, mixture, or other hazardous material. Ensure that the employees have access to and understand the information on these sheets.

In addition to a growing awareness of the need for adequate safety precautions and training, there has been increased recognition of the health effects of prolonged, low-level exposure to many chemicals. However, the latter subject is beyond the purpose and scope of this manual, and you are urged to seek specific guidance from appropriate federal and state agencies and specialized textbooks in this field. See Appendix I, "Sources of Additional Information"; Appendix II, "OSHA Regional Offices"; and Appendix III, "EPA Regional Offices".

3. SAFETY RULES FOR THE CHEMICAL WORKPLACE

Under OSHA regulations, a specific set of safety rules must be developed and communicated clearly to employees. Each employee should attest by signature that he or she has read and understands the safety rules. These rules must be rigidly and impartially enforced. Willful noncompliance can result in dismissal or suspension from the workplace. On the other hand, supervisors should encourage and seriously consider suggestions from the employees for improvements in safety rules, practices, and equipment. Safety meetings should

be held with all employees at regular intervals.

The following are suggested as rules for persons in all chemical workplaces:

- a. Immediately notify your supervisor if you are injured or experience an illness in the workplace.
- b. Wear proper eye protection-American National Standards Institute (ANSI)-approved glasses or goggles-at all times in chemical work, handling, and storage areas.
- c. Always know the hazards and physicochemical properties of the chemicals used (e.g., corrosiveness, flammability, reactivity, and toxicity). Read the label and the MSDS for each unfamiliar or extremely hazardous chemical in the workplace.
- d. Always wear appropriate protective clothing. To minimize exposure to hazardous chemicals, wear clothing that covers the torso, arms, and legs. Confine long hair and loose clothing. Wear shoes that completely cover the feet. Do not wear high-heeled shoes, open-toed shoes, sandals, or shoes made of woven material. Wash work clothes separately from personal laundry.
- e. Never perform any work with hazardous materials when alone in the workplace.
- f. Do not eat, drink, smoke, or apply cosmetics in work areas where laboratory or industrial chemicals are handled or stored.
- g. Do not perform unauthorized work, preparations, or experiments with hazardous materials.
- h. Always wash your face, hands, and arms with soap and water before leaving the work area. This applies even if you have been wearing gloves.
- i. Never engage in horseplay, pranks, or other acts of mischief in chemical work areas.
- j. Never remove chemicals or equipment from the facility without proper authorization.

4. SAFETY FACILITIES AND DESIGN

4.1 General

All chemical work areas should be provided with safety showers, eyewash fountains, approved fire extinguishers, proper ventilation, wash sinks, and appropriate waste disposal facilities. All of these should be conveniently located, properly maintained, and frequently tested. There should be two or more well-marked and unobstructed exits for evacuating the workroom. Aisles and exits must be kept clear at all times. Safety equipment such as showers, eyewash fountains, fire extinguishers, and unrestricted telephones should be readily available, located strategically, and in working order. All employees should be trained in how to use all safety equipment. Special consideration should be given to ensure accessibility to safety equipment by, and ease of evacuation of, workers with disabilities. New construction and renovation of existing facilities should meet the Americans with Disabilities Act (ADA) Accessibility Guidelines. Appendix IV lists minimum design

considerations for construction of laboratories and pilot plants.

A general alarm system, which alerts a facility's emergency and security services, should be provided. This alarm system should have both audible and visual warnings, such as a bell with a flashing light, so that visually or hearing-impaired people are also warned. Automatic smoke and fire alarms are now commonly used and are highly recommended. In some cases, they are legally required, especially in the absence of automatic water sprinklers. Such systems must be properly maintained and monitored, with the results documented on a regular basis to ensure their proper operation. Emergency telephone numbers must be clearly posted.

Highly visible signs, temporary or permanent as appropriate, should be posted in areas where hazardous operations are being carried out or where hazardous chemicals are being used. Exit signs should be tactile (i.e., one should be able to run one's hand along a wall and find the exit sign). The signs should be at an appropriate height for workers who use wheelchairs and those who don't.

Storage of chemicals in laboratories should be minimized. Suitable stockroom or chemical storage space should be used. Laboratory chemical hoods should never be used for long-term storage of any chemicals. *NFPA 45: Standard on Fire Protection for Laboratories Using Chemicals*, published by the National Fire Protection Association (NFPA), gives maximum quantities of flammable and combustible liquids that may be stored as well as maximum container sizes.

Emergency fire drills are essential. In case of general evacuation, employees should be required to go to a designated safe area and remain there until further direction has been given. Establish a safe area of refuge for workers with disabilities; this is simply a designated safe area where workers with disabilities can gather if they need assistance to exit. Discussions with local fire officials should be held to review the special problems of fire containment and handling in the chemical work environment, and such discussions may be mandated by law if the facility must comply with the requirements of Title III of the Superfund Amendments and Reauthorization Act (SARA).

4.2 Protective Clothing

Aprons, lab coats, gloves, safety glasses and goggles, and other protective clothing, preferably made of chemically inert material, should be readily available and used. For further information, see Appendix V. Note that most lab coats and aprons are made of substances that will burn. Experiments or processes involving corrosive or reactive materials, such as strong acids or bases, require the use of goggles and face shields. In the chemical industry, common injuries are cuts to the hands and arms caused by broken glass or mishaps with cutting tools, for example. Cut-resistant gloves are now available that are comfortable to wear and that offer very significantly increased protection against slicing-type injuries, in comparison with cotton or rubber gloves. Cut-resistant gloves should be worn in any situation where a cutting injury is likely. Some examples include cleaning glassware, handling wet and slippery glassware, handling broken glassware, handling glass under stress (e.g., putting a thermometer through a rubber stopper), or performing

cutting operations (e.g., using a razor knife to trim a polymer sample). Note that some of these products are open weave and offer no protection against liquid chemicals; these need to be worn under the appropriate chemical-resistant gloves when chemical protection is needed. Cut-resistant gloves also tend to offer little protection against sticking injuries, such as by a hypodermic needle. Gloves must provide sufficient arm protection to minimize the chance of spilled chemicals making contact with the skin. Selection of proper glove materials is important because most gloves are permeable to some types of chemicals. Contaminated gloves must not be reused. Protection for legs and feet should be provided by a lab coat and shoes and, in some cases, boots. Where necessary, employees should wear other protective equipment such as safety shoes and hard hats.

4.3 Laboratory Chemical Hoods (Formerly Called Fume Hoods)

One key to safe handling of chemicals in enclosed areas is a good, properly installed hood system. The National Research Council's Prudent Practices in the Laboratory: Handling and Disposal of Chemicals and ACS's Handbook of Chemical Health and Safety provide extensive discussions of laboratory ventilation problems. The ANSI Standard Z9.5, Laboratory Ventilation (periodically revised), contains the current recommended guidelines for laboratory chemical hoods. By definition, a hood is any opening that exhausts air. A laboratory chemical hood is different from a biological safety cabinet, laminar flow hood, glove box, or vented enclosure. This manual addresses laboratory chemical hoods and vented enclosures. The same criteria apply to chemical workplaces other than laboratories. Operations where flammable gases, toxic vapors, or noxious odors are given off should be performed in these hoods.

There are a few basic rules about ventilation design. Incoming (i.e., supply or makeup) air must be sufficient to replace and compensate for the exhausted air; otherwise, hood containment will be compromised and contaminants will escape. Exhaust fans should be outside the building to ensure that hood ductwork is under negative pressure. This is done so that if a leak develops in the ductwork, the exhaust will not escape back into the building. Exhaust fans should be as far as possible downwind from all air intakes. Hood exhaust air should not be recirculated. Hoods should not be located in aisles where there is major traffic flow, near open windows and doorways, next to desks, or near sources of cross-drafts. Locate hoods as far to the rear as possible in a laboratory to ensure emergency escape routes. Where possible, locate hoods at the dead end of aisles to minimize traffic flow in front of the hoods.

Careful selection, installation, maintenance, and evaluation of laboratory chemical hoods and vented enclosures are imperative. Many hoods have specific functions. For example, canopy hoods (like those over a kitchen stove) should only be used when the effluents from the operation are forced (e.g., by heating) upward toward the hood. Otherwise, the exhaust is drawn across the worker and his or her breathing zone, no matter how careful the work practices. Slot hoods at the back of laboratory benches are of very limited usefulness.

There are several reasons why face velocity and exhaust rate by themselves

should not be used to determine performance. These parameters are influenced dramatically by cross-drafts caused by operator movements, laboratory traffic flow, location of room doors, nature of the equipment and processes being enclosed, location and type of room air supply, and exhaust air diffusers. In addition, use of higher exhaust rates than necessary is expensive. Active hoods should always be left running, even after hours; otherwise, the materials used in the hood will diffuse back into the work area. Airflows that are too high can also cause turbulence at the face and compromise containment. A higher exhaust rate than is needed for protection is uneconomical as well.

Vented enclosures are intended as alternatives and complements to traditional laboratory chemical hoods. Vented enclosures are less expensive to buy, install, and maintain than traditional hoods. Because they use less air, they are cheaper to operate. Vented enclosures can be custom designed for specific operations (e.g., balance enclosures, microscopes, high-throughput robotic and automatic equipment enclosures, and histopathology operations). When properly designed, they have demonstrated excellent containment. In addition, they usually can be installed or removed in a matter of hours-an important advantage in today's rapidly changing corporate world.

Actual containment tests of installed hoods under conditions of use are recommended. See ANSI/ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) 110-1995 (or current revision), *Method of Testing Performance of Laboratory Fume Hoods*, for specific details of installation and containment testing. Velometers should be used to survey hoods on a regular schedule, at least semiannually, to ensure uniformity of airflow over the face of the hood and to detect any changes. Periodic inspections should be made to determine whether the hood is overcrowded and to check the air tightness of the ducts and exhaust system.

Canopy-style hoods can do more harm than good, for they often draw dangerous vapors from the work area across the head of the worker. Their location, relative to the worker and work area, should be considered carefully. Where appropriate, consider the use of "elephant trunks" (flexible ductwork) as a means of providing local exhaust ventilation.

Once a hood is installed, the responsibility shifts to the users. Periodic and routine maintenance and inspection should be established. This includes inspection of motors, fans, pulleys, and belts, as well as routine lubrication. Always have an emergency plan for hood or electrical failure. The safety department or chemical hygiene officer should establish a routine hood monitoring and evaluation program. Safety personnel should use separate airflow monitors, or anemometers, that are calibrated each year and visually inspect and evaluate all hoods at least annually. Each hood should be marked with a date of inspection, the face velocity, and the proper operating sash height.

All hood users should receive proper training before they ever use a hood. Except for gloved hands and protected arms, no part of the worker's body should ever enter a hood, especially the head. Always wear proper personal clothing, including appropriate eye protection. Always lower the sash whenever the hands-

on operation is completed. Keep the sash fully closed when the hood is unattended. Never shut off a hood unless the hood is clean and decontaminated. Avoid clutter in hoods, and don't use them to store unwanted or unused materials or equipment. Keep light fixtures clean, ground electrical outlets, and keep the outlets free from corrosion and in proper working order. Inspect baffles to ensure they have not slipped shut. Malfunctioning sashes and broken glass should be repaired before the hood is used. Routinely inspect the hood immediately before it is used.

4.4 Sinks

The water supply for laboratory sinks must be separate from that used for toilets, drinking water, and emergency showers or eyewashes. This is necessary to prevent possible contamination of the potable water supply. Back-siphoning or back-pressure can suck sink water into the potable water system through hoses or other apparatuses. Most building codes require a check-valve system that must be tested periodically.

It is advantageous to separate laboratory sink drainage from the sanitary drainage to facilitate independent treatment of each type of waste where this is appropriate.

4.5 Safety Showers

Safety showers should be clearly labeled. ANSI-Z358.1 requires that emergency showers be located no more than a 10-second walk from the hazard. The shower area must be readily accessible and be kept clear of obstructions. Chain pulls should be provided with a large ring. Even better, a double ring at right angles can be installed. The chain should extend down to 48 in. so that short or seated people can reach it easily. The valve should open readily and remain open until intentionally closed. Water flow must be sufficient to drench the subject rapidly and to accommodate more than one person, if necessary. ANSI-Z358.1 requires a minimum flow of 75.7 L/minute (20 gal/minute) of potable water. The water may be tempered. Although an associated floor drain is desirable, its absence should not prohibit installation of a safety shower. The shower should be tested on a regular basis, and a record should be kept of such tests. The shower's location should be clearly labeled.

4.6 Eyewashes

Eyewash fountains should provide a copious and gentle flow of tempered, aerated, potable water for a period of at least 15 minutes (15 minutes of cold water is intolerable). Use of the hands should not be required to maintain the water flow. Eyewash fountains should be tested on a regular basis (activate plumbed installation once a week to flush the lines), and a record should be kept of such tests. ANSI-Z358.1 requires that eyewash units be located no more than a 10-second walk from the hazard. The location should be clearly labeled. A handheld spray wand is an inexpensive and effective adaptation for washing the eyes of people in wheelchairs or those of short stature who are not able to reach a wall-

mounted unit. Portable eyewash units provide an inadequate supply of water, require strict attention to maintenance, and may provide an environment for the growth of microorganisms. Their use should be discouraged except as an interim wash until the injured party can reach a plumbed fixture or in circumstances when running water is not available.

4.7 Respirators and Self-Contained Breathing Apparatuses

Rather than relying on respirators, most workplaces should rely instead on engineering controls, administrative controls, and work practices to limit exposures to hazardous vapors, dusts, and mists.

At least two 30-minute self-contained breathing devices (not cartridge or filter gas masks) should be available for emergency control where high concentrations of toxic vapors, gases, smoke, or oxygen-deficient atmospheres are frequently or potentially present. This equipment should be set in permanent cabinets outside of the danger area. OSHA regulations state that before workers can use a respirator, they must be physically able to. Training (including fit testing) and practice in the use and limitations of all respirators must be given to those who are expected to use them. See the current edition of ANSI-Z88.2, *Respiratory Protection*, and OSHA's *Code of Federal Regulations* (CFR), Title 29, Part 1910.134. Individuals without current certification must not use air-purifying or air-supplied respirators, even during an emergency.

Cleanup of a medium to large toxic spill may require using cartridge or airline-supplied respirators. The requirements of 29 CFR 1910.134 apply. Depending on the situation, you may want to call off-site contractors when the complex degree of service mandated by 29 CFR 1910.134 is required.

4.8 Storage

Keep the number and quantity of stored chemicals to a reasonable minimum. Classify the chemicals by hazard. Separate incompatible materials. Unauthorized access to storage areas must be prevented. Storage equipment must be stable and secure against sliding, tilting, and collapse. In regions subject to earthquakes, restraints should be installed on every shelf. Storage should not be in an area likely to be flooded. In addition, housekeeping in the storage area must be neat and orderly. Storage for large containers of reagents should be provided on a low shelf, preferably in a tray adequate to contain spills or leakage. Chemicals should be arranged in compatible hazard classes (see Appendix VI), not in alphabetical order. Store flammable liquids in a manner that prevents accidental contact with strong oxidizing agents. *NFPA 30: Flammable and Combustible Liquids Code* specifies requirements for flammable liquid storage rooms and storage cabinets.

Keep only minimum quantities of flammable liquids in the workplace, as required by OSHA guidelines and *NFPA 45: Standard on Fire Protection for Laboratories Using Chemicals*. Store larger quantities in approved safety containers or in fire-resistant, properly ventilated solvent cabinets away from ignition sources. Maintain storage for current work only. Large amounts of flammable liquids should be stored in a separate storage building with an automatic fire-

extinguishing system. When a flammable liquid is withdrawn from a drum, or when a drum is filled, both the drum and other equipment must be electrically grounded and bonded to each other.

Never store containers of chemicals on the floor, even temporarily. Keep all stored chemicals, especially flammable liquids, away from heat and direct sunlight. Peroxide-forming chemicals deserve special consideration at all times and particularly in storage. Peroxide formation is accelerated by the presence of UV light and elevated temperature. Maintain careful storage records of compounds that form peroxides upon standing, and periodically review those records. Write the date of receipt of every chemical container on the label.

Chemical storage rooms and buildings must be adequately ventilated, with a recommended air change of at least six turnovers per hour; they must have vents and intakes at both ceiling and floor levels. Every storage room should have at least two exits. Automatic water sprinklers are strongly recommended—except, of course, for spaces where water-reactive materials are stored. Large containers of corrosives should be transported from central storage in a chemically resistant bucket or other container designed for this purpose. When transferring from a metal container to a nonelectrically conductive container, ground the metal container. Only small quantities should be transferred to glass, plastic, or other nonelectrically conductive containers. For additional protection for the eyes, never store corrosives above chin level.

4.9 Labeling

ANSI Z129.1-2000, *Hazardous Industrial Chemicals-Precautionary Labeling*, should be consulted. The OSHA booklet 3084, *Chemical Hazard Communication*, summarizes the federal regulatory requirements for the labeling of containers in the workplace. Because state regulations may vary, consult them also.

All chemicals should be labeled with the date received and expected shelf life. Chemicals that are repackaged should have secure, waterproof labels, marked with waterproof ink, that contain information about hazards as well as the chemical name, date packaged, and strength or purity.

4.10 Electrical Hazards

OSHA regulations require that all electrical outlets have a grounding connection for use only with three-pronged plugs. If equipment is not equipped with a three-pronged plug, follow the requirements of the *National Electrical Code* (NEC), and replace the cord and plug with a three-wire cord and three-pronged plug. Protect all electrical outlets with ground-fault interrupters; note that the NEC requires that all outlets within 6 feet of any source of water be so protected.

Polarity of outlet wiring and continuity of grounding connections, including leads to the building ground system itself, should be checked regularly by an authorized inspector. The NEC should be followed in all installations. This includes proper grounding as well as proper equipment for hazardous areas.

The condition of wiring, plugs, cords, and related equipment should be frequently inspected. Wiring that is frayed or worn should be replaced. Wiring

should never be stretched across the floor where someone could trip over it. Eliminate obstructed switchgear and panel boards, unlabeled panel boards, electrical outlets with open (or missing) cover plates, and excessive use of extension cords.

All personnel should know the location of circuit breakers and how to cut off all electrical service in case of a fire or accident. All circuit breakers should be labeled properly.

The OSHA Standard 29 CFR 1910.147, The Control of Hazardous Energy (Lockout/Tagout), covers the servicing and maintenance of machines and equipment in which the unexpected energizing or start-up of the machines or equipment, or release of stored energy, could cause injury to employees. This standard establishes minimum performance requirements for the control of such hazardous energy.

4.11 Hearing Protection and Noise Control

Hearing conservation should be practiced through proper design, modifications of existing sources of noise, and the use of ear protection. Ear protection includes earmuffs and earplugs. Generally, earmuffs have a greater attenuation factor than earplugs.

OSHA-allowable occupational noise exposure limits contained in 29 CFR 1926.52 are listed in Table I. Exposure to impact noise should not exceed a 140-dB peak sound pressure level.

TABLE I
OSHA Occupational Noise Exposure Limits

Duration Per Day, h	Sound Level, dBA Slow Response*
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

*Decibels when measured on the A-scale of a standard sound level meter at slow response

4.12 Eye Protection

The use of proper eye protection is a minimum requirement for everyone who enters a chemical work area. The type of eye protection needed depends on the circumstances. There is always a danger of splashing chemicals or flying particles.

Therefore, goggles or other forms of eye protection that protect both the front and sides of the eyes are mandatory. Side shields offer some protection from objects that approach from the side, but they do not provide adequate protection from chemical splashes, which can drip behind glasses. Face shields and goggles may be appropriate when working with glassware under reduced or elevated pressure and with glass apparatuses used in combustion or other high-temperature operations. Face shields alone are not considered adequate eye protection, according to ANSI Z87.1-2003, and must be used in conjunction with other eye protection. The current ANSI standard, ANSI-Z87.1-2003, *Occupational and Educational Personal Eye and Face Protection Devices*, should be considered the minimum protection. Goggles should be worn when working with compressed gases.

There is no published evidence to support the traditional belief that wearing contact lenses in a chemical environment increases the risk of eye injuries. A careful study of the literature by knowledgeable consultants has refuted the perceived risks. Because of the ever-increasing use of contact lenses and the benefits they provide, the CCS members, having studied and reviewed the issue, are of the consensus that contact lenses can be worn in most work environments, provided that the same approved eye protection is worn that is required of other workers in the area. Contact lenses by themselves do not offer adequate eye protection in any environment in which the chance of an accidental chemical splash can reasonably be anticipated. Appropriate eye protection should always be worn in such situations, in accordance with OSHA's Personal Protective Equipment Standard (29 CFR 1910.132 and 133) and ANSI Z87.1-2003, *Occupational and Educational Personal Eye and Face Protection Devices*. The National Institute for Occupational Safety and Health (NIOSH) Publication No. 2005-139, *Contact Lens Use in a Chemical Environment*, can be viewed at www.cdc.gov/niosh/docs/2005-139 (accessed Aug. 25, 2005).

Before working with chemicals, have an action plan in case of a chemical splash near the face or eyes. For splashes, immediately flush the eyes with tempered potable water from a gently flowing source for at least 15 minutes. Hold the eyes open to wash thoroughly behind the eyelids. An eyewash fountain should be used, but if one is not available, injured persons should be placed on their backs and water gently poured into their eyes. This must be followed by prompt treatment by a member of a medical staff or an ophthalmologist specializing in chemical injuries to the eyes. Emergency response planning should include arrangement with an ophthalmologist who may issue standing instructions to staff medical personnel. All injuries, especially eye injuries, should be treated and reported to ensure maximum attention and feedback to be used in programs designed to prevent future accidents.

Considerable discomfort and damage to the eyes can result from exposure to ultraviolet (UV) light. Absorption of this radiation by the outer layers of the eyes (cornea and conjunctiva) produces conjunctivitis that gives the sensation of sand in the eyes. All personnel should wear protective glasses whenever they may be exposed to UV radiation. Use of lasers requires special care. (See Part II, Section 12.3.)

4.13 Ergonomics

Ergonomics is the science of fitting workplace conditions and job demands to the capabilities of the working population. Effective and successful “fits” assure high productivity, avoidance of illness and injury risks, and increased satisfaction among the workforce. Although the science of ergonomics is broad, the term most commonly refers to those work-related factors that may pose a risk of musculoskeletal disorders and recommendations to alleviate them. For a good introduction to this area, see NIOSH Publication No. 97-117, *Elements of Ergonomic Programs: A Primer Based on Evaluations of Musculoskeletal Disorders*.

5. WASTE DISPOSAL

5.1 Introduction

The management of industrial waste in the United States, especially hazardous waste, is highly regulated at the federal and state levels. Waste disposal costs have steadily risen, and the civil and criminal liabilities associated with improper management present numerous concerns to small businesses. Liabilities for proper packaging, transportation, paperwork, and disposal all rest primarily with the waste generator. While all waste is of concern, this discussion will focus primarily on hazardous waste, which represents both the greatest cost and the greatest potential liability to small businesses.

5.2 Proper Planning

Proper planning is required to minimize the cost of disposal and the potential liabilities. First and foremost is a clear understanding of the nature of the waste generated. A “waste determination” is the first step in proper planning; the waste “stream” must be evaluated to determine whether or not it is regulated as hazardous. Several sources of information are helpful in completing this evaluation, including 40 CFR 260-399, which is available online at www.epa.gov/docs/epacfr40/chapt-I.info (accessed Aug. 26, 2005). These parts are in two volumes. Because the regulations that apply to your business are usually state specific, it will also be helpful to call the state environmental agency (listed in the blue pages of most phone books) to request a copy of the state’s hazardous waste regulations. These publications are usually free and may be available electronically from the agency’s website. See www.epa.gov/docs/epacfr40/find-aid.info/state (accessed Aug. 26, 2005) for state agencies.

A crucial aspect of planning is a clearly defined line of responsibility for chemical waste management. This means that one employee should be assigned responsibility for coordinating the management program. This person should become familiar with regulatory requirements, develop internal handling procedures, and work with contractors. The employer must provide support for the program, particularly with respect to adequate space for storage and handling with suitable safety features. This should include secondary containment in the event of leaking containers.

All employees must recognize the value of good housekeeping practices, especially in terms of identification and labeling of waste materials. In any operation where waste is generated, chemicals should be segregated. When mixed together, hazardous waste and nonhazardous waste are usually regulated as hazardous, thereby increasing the volume of material and the cost for disposal. If waste chemicals are to be disposed of off-site, good segregation will result in more disposal options.

Pollution prevention and waste minimization strategies should be employed whenever possible to reduce costs and liability. Some strategies include the following:

- a. *Training*: Each individual must choose to minimize chemical waste for the program to work successfully. Personnel should be trained when they are first hired, yearly thereafter, and when procedures change.
- b. *Chemical Redistribution*: Unopened or unused portions of chemicals may be redistributed within the organization. If a chemical is needed, especially an exotic, high-hazard, or single-use chemical, check with other personnel and colleagues for availability before ordering.
- c. *End of Process Treatment*: Write end of process treatment procedures into standard operating procedures and use them. An example would be to conduct “in container” neutralization of an acid with a base and to flush the mixture to the local sewer with excess water.
- d. *Process Modification*: Encourage the modification of processes to decrease the quantity of hazardous chemicals used and generated. Where possible, use micro and semi-micro techniques to reduce the volumes of waste generated.
- e. *Product Substitution*: Substitute nonhazardous or less toxic materials in your chemical processes and experiments. Some examples include the following:
 - High-flashpoint scintillation fluids (e.g., Ecoscint)
 - Non-mercury thermometers (e.g., Enviro-Safe™)
 - Detergents and enzymatic cleaners in place of sulfuric acid and potassium dichromate (Chromerge) cleaning solutions and ethanol and potassium hydroxide cleaning solutionsAvoid the use of known carcinogens, reproductive toxins, or extremely hazardous chemicals where possible.
- f. *Recycling*: Some precious metals and valuable chemicals may be collected for recycling by outside contractors to reduce waste disposal costs. Examples include the following:
 - Reclamation of silver from photo-fixing chemicals
 - Collection of mercury (e.g., thermometers and lamps) for distillation by an outside recycler
 - Collection of surplus electronics (e.g., computers) for recycling by an outside recycler
- g. *Segregation and Characterization*: Do not consolidate various process or experiment wastes into the same container unless the wastes contain similar constituents or you are otherwise authorized to do so. Accurately label waste containers, including all chemical contents and approximate percentages.

Segregation and characterization simplifies the waste stream, facilitating treatment and disposal.

- h. *Inventory Control*: It is important to audit chemical supplies and use inventory control measures. Purchase only the quantity of chemical required for a specific project, and do not stockpile chemicals unnecessarily. Chemicals in storage should be examined periodically for changes in the condition of the chemical, the container holding the chemical, and the storage area. Signs of degradation-such as split caps, the accretion of deposits on the bottles or on shelf surfaces in the storage area, and the formation of two phases or a change in the physical state or the formation of crystalline structures within liquids-should be corrected immediately or else the chemical should be disposed of. Some changes in the chemical may not be readily visible (e.g., formation of peroxides in ether). Before using or storing chemicals, become familiar with their physical and chemical hazards.
- i. *Storage Practices*: Chemical containers should be stored and segregated according to their hazards (e.g., flammables, acids, bases, oxidizers, reactives, poisons) and incompatibilities. Measures such as secondary containers to protect the stock container may be required to safely store a particular chemical. Information on the specific hazards is available on the chemical's MSDS. Caution must be taken to ensure that chemicals are stored in a safe manner. Examples include the following:
- Water-reactive chemicals are not to be stored under sinks.
 - Acids are not to be stored under sinks.
 - Flammable chemicals are not to be stored near ignition sources.

All containers must have an appropriate container label that is intact and legible at all times. Any defaced, faded, or separating labels should be addressed immediately. Proper labeling practices by all personnel will eliminate unknown chemicals being passed on to future personnel responsible for maintaining the workspace. Expiration dates should be clearly marked for chemicals that are in reactive groups or that develop hazardous functional groups upon long-term storage (e.g., peroxide-forming chemicals).

In general, it is prudent to consider all waste chemicals to be hazardous waste unless there are good reasons to consider a specific material to be nonhazardous. Before shipping hazardous waste off-site for disposal, the company will need a generator identification number from the U.S. Environmental Protection Agency (EPA) or your state environmental agency. There is no cost to acquire an identification number; call your state environmental agency to obtain the proper form. It can also be obtained online from EPA at www.epa.gov/epaoswer/hazwaste/data/form8700/forms.htm (accessed Aug. 26, 2005). In addition to properly classifying chemical waste, companies are obligated to meet requirements within designated generator categories based on the quantity of hazardous waste on the premises. For example, large companies are typically required to remove accumulated waste every 90 days, whereas smaller companies that generate smaller quantities may be able to store waste for longer periods. Facilities designated as "small-quantity generators"-those that generate 100-1,000 kg of hazardous waste

in any given month-may store their waste for 180 or 270 days, depending on the location of their designated disposal facility. Still smaller generators (those that generate less than 100 kg in any given month) may store their waste indefinitely under some conditions.

All generators must ship waste off-site by using a hazardous waste manifest that tracks waste from "cradle to grave"-from the time the waste is first generated until its ultimate destruction. Appropriate labeling, marking, and placarding requirements also apply.

5.3 Waste Definitions

A material is usually defined as a waste when it is determined that the material should no longer be used and it is time to discard it. In the past, the laboratory or plant worker was often the one who determined when an unwanted material was to be declared a waste; more recently, federal and state regulations have expanded our understanding of what constitutes a waste. Thus, according to federal regulations, a material is also a waste, for example, if it has been abandoned or if it is considered to be "inherently wastelike". This means that a material that has been spilled, degraded, or obviously contaminated is often considered to be a waste, according to the regulations.

In the United States, disposal of certain chemical wastes is governed by the requirements of the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments of 1984. RCRA is administered by EPA and authorized state environmental agencies. Note that regulations promulgated by state and local jurisdictions take precedence over federal regulations and may be different or more restrictive. Obtain detailed, up-to-date information from state environmental agency offices. For details on the federal RCRA regulations, consult 40 CFR 260-268 (available online at www.epa.gov/docs/epacfr40/chapt-I.info) (accessed Aug. 26, 2005).

Under federal regulations, any material that is discarded or intended to be discarded is considered a **solid** waste (regardless of its physical state). A subset of solid waste is hazardous waste, which must meet certain criteria defined in RCRA in two categories: characteristic waste and listed waste. (See Section 5.4.)

Most companies that generate hazardous waste work with a disposal contractor or consultant to arrange for off-site disposal. Competent contractors can provide a number of valuable services, but it is important to understand that the waste generator retains virtually all liability for the proper packaging, transportation, and disposal of waste. Great care should be taken in the process of selecting a contractor, including a review of references, qualifications, capabilities, insurance, and permits, as applicable.

A competent contractor must be able to do all of the following:

- a. Properly package waste according to U.S. Department of Transportation (DOT) requirements
- b. Label waste according to EPA and DOT requirements
- c. Prepare necessary forms, including disposal facility approval documents and the waste manifest used for transportation

d. Transport waste to a permitted treatment, storage, or disposal facility (TSDF). Although contractors may assert that they “take title to” hazardous waste or otherwise claim responsibility for its proper disposal, it is important to understand that the generator, not the contractor, always maintains responsibility for the waste, from cradle to grave.

Under another federal law, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, frequently referred to as Superfund, generators may be held liable for cleanup costs if their hazardous waste or other waste from other generators, all located in the same disposal location unit, poses a threat to human health or the environment. This concept, referred to as joint and several liability, emphasizes the importance of choosing good contractors and facilities for waste disposal.

5.3.1 Waste Classification

EPA waste classification terminology is quite specific and cannot necessarily be inferred from a general knowledge of chemistry. This section is helpful in determining the status of various wastes based on their characteristics or listing. The status of a material as a hazardous or nonhazardous waste depends on its identification as possessing one or more of four characteristics and/or on its identification as a material named in one or more of the listed wastes. All waste determinations are based on evaluating the material against these standards. Sending a representative sample to a properly accredited environmental laboratory for a determination of toxicity is advisable. Wastes from a number of industrial processes are also regulated as hazardous, as are many common commercial products. There are four characteristics of hazardous wastes: ignitability, corrosivity, reactivity, and toxicity. The four characteristics are defined as follows:

- a. **Ignitability.** A waste material is classified as ignitable (EPA Waste Number D001) if it is
 - A liquid (other than an aqueous solution containing less than 24% alcohol by volume) and has a flash point of less than 60 oC (140 oF);
 - Not a liquid and is capable under standard temperature and pressure of causing fire through friction, absorption of moisture, or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard;
 - An ignitable compressed gas (as defined in 49 CFR 173.300); or
 - An oxidizer (as defined in 49 CFR 173.151).
- b. **Corrosivity.** A waste material is classified as corrosive (EPA Waste Number D002) if it has either of the following properties:
 - It is aqueous and has a pH equal to or less than 2 or greater than or equal to 12.5 using EPA test methods, or
 - It is liquid and corrodes steel (SAE 1020) at a rate greater than 6.35 mm (0.25 in.) per year at a test temperature of 55 oC (130 oF).
- c. **Reactivity.** A waste material is classified as reactive (EPA Waste Number D003) if it has any of the following properties:

- It is normally unstable and readily undergoes violent change without detonation;
 - It reacts violently with water;
 - It generates toxic gases, vapors, or fumes when mixed with water;
 - It is a cyanide- or sulfide-bearing waste that generates toxic gases, vapors, or fumes at a pH between 2 and 12.5;
 - It is capable of detonating or exploding when it is subjected to a strong initiating course or if it is heated under confinement; or
 - It is a forbidden Class A or Class B explosive as defined by DOT.
- d. **Toxicity.** A waste is classified as toxic by RCRA (EPA Waste Numbers D004-D043) if an extract from the Toxicity Characteristic Leaching Procedure (TCLP) test results in a waste leachate above certain concentration levels. The TCLP list includes a number of toxic metals, pesticides, and solvents that are regulated as hazardous if the leaching test indicates they may leach in sufficient concentrations to pose a threat to groundwater. Included on the list are 8 common metals (As, Ba, Cd, Cr, Hg, Pb, Se, Ag), 20 solvents, and 12 pesticides. The list and the levels are provided in 40 CFR 261.24.

Wastes are named in lists found in 40 CFR 261.31-261.33. These wastes are materials generated through either specific or nonspecific processes and include materials such as spent solvents, which are frequently generated by both laboratory and manufacturing facilities. The lists also include numerous commercial products that are regulated as hazardous wastes when they are discarded, such as many common laboratory reagents.

5.3.2 Mixed Waste

Some waste generated by companies may present a combination of chemical, radioactive, and/or biological hazards; this is generally referred to as mixed waste. Although much of the previous discussion on chemical hazardous waste may apply, this waste may require special management considerations because the treatment method for one of the hazards may be inappropriate for the treatment of one or more of the others.

The management of mixed waste is further complicated by legal requirements that may not be consistent with the risks of each of the different hazards present. Thus, chemical waste is regulated by RCRA, and radioactive waste is regulated by the U.S. Nuclear Regulatory Commission. Various states also regulate medical/infectious waste. There are currently few options for disposal of mixed RCRA-defined wastes and radioactive wastes; such wastes are mostly stored on-site, pending the permitting of facilities designed to treat multiple hazards. More information is available at the following Web page: www.epa.gov/epaoswer/-hazwaste/radio/index.htm (accessed Aug. 26, 2005). If the chemical waste contains biological waste (e.g., human blood in dental amalgam waste), the chemical waste contractor may allow the biological component to be treated prior to collecting the material. Check with your disposal company and state environmental agency to determine what options are available.

5.3.3 Universal Waste

Universal waste includes fluorescent bulbs, batteries, and pesticides. While this waste may be considered RCRA-defined hazardous waste, federal regulations were created to allow longer on-site storage and expanded disposal options, with a goal of increasing the amount of recycling of this waste. More information is available at the following EPA website: www.epa.gov/epaoswer/hazwaste/id/univwast (accessed Feb. 1, 2007).

5.3.4 Biohazard Waste, or Regulated Medical Waste

Waste containing biological materials is regulated by each state. More information is available at www.epa.gov/epaoswer/other/medical (accessed Aug. 26, 2005).

5.3.5 Electronics

The average cathode ray tube computer monitor contains 4 lb of lead and may be regulated as RCRA-defined hazardous waste. However, when recycling options are used, this material may be allowed to go to a recycling facility. More information can be found at EPA's recycling website: www.epa.gov/epaoswer/hazwaste/recycle/ecycling (accessed Aug. 26, 2005).

5.4 Getting Help

There are a number of resources that are available to help small businesses make waste determinations and properly manage waste. These different options are described below.

5.4.1 Regulators

State and federal regulators can be helpful both in supplying copies of applicable regulations and in giving interpretations as required. In addition, lists of permitted transporters and disposal facilities are usually available. It is also possible in many cases to obtain regulatory compliance information on potential vendors.

5.4.2 Consultants

Qualified consultants may be helpful in providing unbiased opinions on vendor qualifications, and can often provide regulatory interpretations, waste determinations, packaging advice, and an interface with regulators. In the event of a reportable spill involving contamination of the environment, most government agencies will require the company to hire an independent consultant to develop a remediation plan and oversee the cleanup. Consultants typically charge an hourly or project fee for their services. Qualifications vary considerably; certifications may be helpful in determining competence. References may also be requested.

5.4.3 Waste Brokers

Waste brokers can provide many of the same services as consulting firms, but they usually specialize in arranging shipments of waste into disposal facilities.

Unlike consultants, brokers usually pay the transporter and disposal facility directly and mark up these rates. The generator may not be aware of all the arrangements made on its behalf and should take steps to verify proper transportation and disposal. References should be requested.

5.4.4 Transporters

Transporters frequently act as waste brokers, arranging shipments directly with the disposal facility and billing for these services. Costs may be lower because there are no markups on transportation. Proper permitting and insurance should be verified.

5.4.5 Environmental Training

If facility personnel are available to take a more active role in the off-site shipments of waste, there are a variety of commercial training programs offered. Commercial environmental magazines (many of which are free) can give details on upcoming courses. The National Environmental Training Association certifies trainers and can also provide information on available courses. *Federal regulations require training of individuals who handle hazardous waste.*

5.4.6 Disposal Facilities

Permitted TSDFs, which may include incinerators, treatment plants, waste consolidation facilities, and landfills, can provide information on acceptance of wastes at their location. In many cases, permits are more restrictive than the regulations for wastes accepted, packaging methods, analysis required, and other factors. Copies of permits and insurance certificates should be requested. Many TSDFs also offer consulting, transportation, packaging, and cleanup services. The generator should be aware of the final disposal method and location for all shipments, as well as the long-term liability for the waste materials. For this reason, financial stability and a good regulatory complaint record are requirements for the TSDFs.

5.4.7 Trade Associations

Trade associations can frequently allow a company to combine with other firms to share resources. This might include joint training sessions, shared transportation, competitive contracts for multiple facilities, references, and general advice.

5.4.8 Large Local Businesses

Large industrial firms are a good source of references because they usually have the resources to verify proper handling. It may also be possible to arrange for shared transportation in certain circumstances.

5.4.9 Books and Other References

There are many reference materials available to help; some of these are free of charge. The EPA manual entitled *Managing Your Hazardous Waste: A Guide for Small*

Businesses is particularly recommended. Request this title online at www.epa.gov/epaoswer/hazwaste/sqg/sqghand.htm (accessed Aug. 26, 2005).

EPA's Office of Small Business Ombudsman is an extremely useful resource for both regulatory information and documents. For additional titles and sources, see the inside front cover of this manual and Appendix I. Scientific equipment distributors are another source of information.

5.5 Summary

Economic and liability concerns dictate careful management of hazardous waste. The following are some general do's and don'ts for businesses that generate hazardous waste:

- a. DO keep accurate records of all shipments of hazardous waste, preferably forever, as Superfund liability may be mitigated by accurate record keeping.
- b. DON'T pour any hazardous waste onto the ground, into the sewer, or into municipal waste containers. Don't burn any waste at the site without a permit.
- c. DO determine the final disposition of the waste materials. Request certificates of destruction or disposal from TSDFs.
- d. DON'T mix wastes together except for compatible flammable solvents or other clearly compatible wastes.
- e. DO look at all processes that generate chemical waste to see if less hazardous materials can be substituted, and minimize all waste generated by poor housekeeping practices.
- f. DON'T automatically hire the cheapest contractor without concern for the liability of proper disposal of your waste. Always check references, insurance, and permits when applicable.
- g. DO attend seminars, training sessions, or workshops to learn more about the regulations and your disposal options.
- h. DON'T ignore spills or releases of hazardous materials. Investigate the need to report these releases, and clean up all small spills promptly.
- i. DO investigate working with other companies in the area to share transportation costs. Communicate with other companies in the same industry to find out how they handle waste materials.
- j. DON'T accept samples of chemicals that will not be used. Don't give away surplus chemicals unless you know they are going to someone who will actually use them. You may have liability if someone else improperly disposes of your chemicals.
- k. DO select a key employee to manage the hazardous waste, and make sure this employee receives the needed support.

6. PREPARATION FOR MEDICAL EMERGENCIES

This manual does not address specific first aid treatment. In Part II, proper handling techniques are discussed, as well as symptoms of overexposure to certain selected chemicals. We strongly recommend that, for all chemicals used in the

workplace, both the MSDSs and competent medical authorities be consulted in advance regarding first aid treatment. First aid supplies approved by a consulting physician should be readily available. For specific guidelines on appropriate first aid training, see *OSHA's Guidelines for First Aid Training Programs*, Directive CPL 2-2.53, January 7, 1991, available at www.osha-slc.gov/SLTC/medicalfirstaid/-index.html (accessed Aug. 26, 2005).

In planning for potential emergencies, consult with local emergency personnel in advance and establish plans for the handling of chemical emergencies. At a minimum, make the following preparations:

- a. Always have first aid equipment readily available.
- b. Post in obvious places the locations and phone numbers of the local physicians qualified to handle chemical emergency cases and the locations and phone numbers of local medical facilities. Also post the telephone number of the local poison control center and the location of the MSDS file.
- c. Train sufficient staff in basic first aid and cardiopulmonary resuscitation (CPR). If automatic external defibrillators (AEDs) are part of the emergency equipment, staff members should be trained in how to use them. American Red Cross certification or its equivalent should be encouraged for all personnel.
- d. Develop procedures to ensure that someone knowledgeable about the accident always accompanies the injured person and that copies of the appropriate MSDSs are sent with the injured person.
- e. Establish procedures to ensure that, following any first aid, only a nurse or physician qualified to handle chemical emergencies provides further examination and treatment.

There are other preparations to be made in advance for medical handling of emergencies involving the chemicals used in the workplace. For example, if first aid treatment is not described in the MSDS, a recommended practice is to add this information to the MSDS with minimum delay. Examples of emergencies that you should anticipate follow:

- a. Thermal, cryogenic, and chemical burns
- b. Cuts and puncture wounds from glass or metal that is contaminated with chemicals
- c. Chemicals (liquid, dust, glass) in the eye
- d. Skin irritation by chemicals
- e. Poisoning by ingestion, inhalation, skin absorption, or injection
- f. Asphyxiation (chemical or electrical)
- g. Lachrymatory vapor irritations

6.1 Chemical Toxicity

Almost all of the chemicals in the workplace and laboratory are toxic to some degree. The two most likely routes of exposure to a toxic chemical are by inhalation and by absorption through the intact skin. Injection (e.g., from a contaminated needle or broken glass fragment) and ingestion are also possible. Accordingly, protection from all four routes of exposure is necessary.

Toxic effects can be immediate or delayed, reversible or irreversible, local or systemic. The toxic effects of chemicals can vary from mild and reversible, such as a headache from a single episode of inhaling the vapors of petroleum naphtha that disappears when the injured person gets fresh air, to serious and irreversible, such as birth defects from excessive exposure to certain materials during pregnancy or perhaps cancer from extended chemical exposure.

The toxic effects from exposure to a chemical depend on the severity of the exposure. Generally, the greater the exposure (quantity, frequency, and duration), the more severe the result. There are the concepts known as the Threshold Limit Value (TLV) and OSHA's Permissible Exposure Limit (PEL). For example, the TLV, and PEL, for phenol is 5 ppm. According to the definitions for these terms, a normal person can inhale in his or her breathing air 5 ppm of phenol vapor for 8 hours a day, 40 hours a week, for a working lifetime without harmful effects. Since some people may not be "normal" in their reaction to phenol, any person's exposure to phenol vapor should always be as low as possible-and never exceed for even a very short time the limit of 5 ppm.

MSDSs for hazardous chemicals and mixtures of hazardous chemicals cite the TLVs or PELs for the chemicals or mixtures. Employers should insure by appropriate measurements of the breathing air that all persons who work with hazardous chemicals are exposed at concentrations less than the TLV or PEL. Most certified industrial hygienists are qualified to make the appropriate measurements and to suggest ways to improve the ventilation or to recommend appropriate respirators when the limits are exceeded. However, respirators are uncomfortable to wear for long periods and cannot be used by persons with beards or persons who suffer from respiratory difficulties. Engineering controls to prevent the escape of hazardous vapors, mists, and dusts are preferable.

An MSDS cannot cite a TLV or PEL if the limit has not been established. In rare cases, the chemical is not harmful to inhale, and no limit is necessary. More often, the chemical will be harmful when inhaled, and employees must be protected. In such instances, an industrial hygienist can offer advice.

An MSDS also describes other hazardous characteristics of a chemical or mixture. Thus, if a chemical can be absorbed through the intact skin, the MSDS will so state and will also prescribe the use of protective equipment, such as gloves or full protective clothing, as appropriate. If the MSDS does not specify the material (e.g., rubber, neoprene, or polyethylene) for the protective equipment and the supplier cannot suggest a suitable material, an industrial hygienist can assist in the selection of the proper material.

Reproductive toxins adversely affect the reproductive process. Examples are mutagens, which can cause damage to chromosomes in males and females, and teratogens, which can affect fetal development or cause birth defects, including fetal death. For the best available and up-to-date information, refer to DART/ETIC (Developmental and Reproductive Toxicology/Environmental Teratology Information Center), a bibliographic database on TOXNET (National Library of Medicine Toxicology Data Network). Go to www.sis.nlm.nih.gov and click on "TOXNET" under "Environmental Health and Toxicology". NIOSH has a website

that contains information on female and male reproductive health issues, including chemicals and radiation. See www.cdc.gov/niosh/topics/repro (both sites accessed Aug. 26, 2005). Two useful and recommended books are *Reproductive Hazards of the Workplace* and *Catalog of Teratogenic Agents*, 10th edition.

A variety of allergens (agents that can produce an immunologic reaction) may be encountered in the workplace when suitable precautions are not enforced. Further, some chemicals evoke nonimmunologic reactions in individuals who are sensitive to them. Typical responses include dermatitis or asthma. The special problem is one of sensitization, and difficulties also arise because the allergic response may not be readily identifiable. Thus, there is usually no physical reaction at the time of initial exposure, although this is the point at which sensitization may have occurred. The physical reaction then takes place after the next or some subsequent exposure. There is no comprehensive list of substances causing these effects.

There are many factors influencing the toxicity of chemicals, some known, some not yet fully understood. Hence all chemicals should be handled with respect for their known or potential hazards. Employers should ensure that workplace exposures to chemicals are always maintained at the lowest possible levels. The skin, eyes, and respiratory tract should always be protected from possible exposure by use of engineering controls, appropriate protective equipment, ventilation controls, and safe work practices, including personal hygiene practices. Eating, drinking, smoking, and the application of cosmetics should be strictly prohibited in all work areas where lab or industrial chemicals are handled. Thorough washing with soap and water should be mandatory at the end of a workday and before leaving the area during a break. These precautions can go a long way toward preventing undesirable toxic consequences.

6.2 Material Safety Data Sheets

MSDSs are references intended primarily to train workers in the hazards of and precautions for chemicals that they will use in an industrial workplace. OSHA defines a hazardous substance as any chemical that presents a hazard under normal-use conditions or in a foreseeable emergency. OSHA requires that all hazardous chemical suppliers furnish MSDSs to their customers and that employers make them readily available to their employees for every hazardous chemical on the premises. MSDSs can be stored in databases, provided that workers can readily access them.

OSHA has prepared a suggested format for MSDSs, but any format that supplies the information required by 29 CFR 1910.1200 is acceptable. Regardless of format, the principal topics required in an MSDS include physical data, fire and explosion hazards, toxicity hazards, other health hazards, propensity to react vigorously (often called an incompatible chemicals list or reactivity description), spill cleanup procedures, and precautionary measures that will materially reduce the probability of harm. OSHA requires that known and suspected carcinogens recognized by relevant authorities be identified in MSDSs. A properly prepared MSDS is a useful tool to train employees in descriptive and theoretical chemistry

as well as accident prevention. Part II, Section 2.2, contains an explanation of how to read and understand MSDSs. Many employers use MSDSs as part of the employee training required by OSHA. (See next section.)

6.3 Technical Guidance

Both EPA and OSHA rules state that most businesses handling chemicals in any way must designate a person or persons in the organization to be responsible for emergency response measures and for the safe use of hazardous chemicals in the workplace and in the laboratory.

Under EPA rules, the designated person is called an emergency coordinator. This person must either be on the premises of the facility or on call at all times. The responsibilities of, and need for, the coordinator are spelled out in detail in 40 CFR 265.55 and 265.56. In general, this individual has the responsibility for coordinating the necessary emergency response measures. The person must be thoroughly familiar with the entire facility and must have authority to act on behalf of the management in all respects.

Under OSHA, two separate regulations apply: one to the industrial workplace, called the Hazard Communication (or Right-to-Know) Standard, 29 CFR 1910.1200, and the other to most laboratory work, called the Laboratory Standard, 29 CFR 1910.1450.

The designated person under the Hazard Communication Standard is not identified by a specific name. Here, we will use the term safety officer. This individual may also function as the emergency coordinator and as the chemical hygiene officer.

Under the Hazard Communication Standard, the employer is required to prepare and implement a written hazard communication program describing the procedures for the safe use of chemicals and the training of employees. See 29 CFR 1910.1200 for details. The safety officer might be charged with the responsibility for preparing the hazard communication program and the training program, as well as supervising the implementation of the hazard communication program.

In a large facility, a safety committee may be desirable to assist the safety officer. Hazardous conditions should be reported and corrected. Giving a serial number and date for each hazardous condition is helpful in keeping track of such conditions until they can be corrected.

In practice, a revolving safety committee membership is preferable because it brings the judgment of more individuals into the system. The person responsible for an area in which a hazard is identified should be formally advised of the hazard and should be given suggestions and deadlines for corrections. After corrective measures have been completed, the person responsible for the corrective action should report to the safety officer. Periodically, the safety officer should review past reports for recurring hazards and act to eliminate them after consulting with management and others for suggestions. It is normally helpful to carry out such review procedures in the manner of a formal safety audit. Appendix VII suggests some areas and operations that should be reviewed. Refer to the references in Appendix I for further information concerning safety audits.

Usually, the safety officer has the responsibility for reviewing the safety rules with all new employees, and periodically, with all employees. The safety officer also participates in revising these rules.

A Chemical Hygiene Plan is required for laboratories where multiple chemical procedures with hazardous chemicals are carried out using containers that can be easily and safely manipulated by one person and where protective laboratory equipment and practices are available and used, provided that the laboratory work does not include the production of commercial quantities of materials. (Laboratories whose function is to produce commercial quantities of materials are guided by the provisions of the Hazard Communication Standard.)

The written Chemical Hygiene Plan, which must be annually reviewed and updated if necessary, must be capable of protecting employees from health hazards associated with the chemicals used, as well as keeping exposures below the PELs that are specified in 29 CFR 1910, Subpart Z.

Specifically, the Chemical Hygiene Plan includes the following:

- a. Designation of a chemical hygiene officer
 - b. Standard operating procedures for the laboratory
 - c. Provision for establishing "designated areas" for working with and storing select carcinogens, reproductive toxins, and highly toxic substances
 - d. Criteria used to insure that control measures keep exposures below the PELs
 - e. A requirement for properly functioning and maintained hoods
 - f. Provisions for employee information and training
 - g. A description of circumstances under which a laboratory operation requires prior approval from the employer
 - h. Provision for medical consultation for employees
- Refer to 29 CFR 1910.1450 for details.

6.4 Accident Reporting

All accidents should be reported. Accidents resulting in even minor medical treatment or observation must be recorded. A formal, written report stating the causes and consequences of each accident should be made to the designated authorities, including the insurance carrier. Recommendations for the prevention of recurrences should be discussed with the safety officer.

A written report of each accident should be submitted to management and to the safety officer, who should take appropriate measures to prevent recurrence. A periodic review of accident reports will often reveal problem areas that need special attention. If the accident causes a lost time condition, it must be reported on OSHA Form 200. Unusual or unexplainable chemical accidents should be reported in the Letters to the Editor column of *Chemical & Engineering News* to alert others.

6.5 Safety Inspections and Audits

Accidents are caused by mistakes. Clearly, even though regular inspections and audits cannot prevent every accident-causing mistake, it is worth the expenditure of some time and effort to conduct more than just occasional inspections and audits. The following discussion is introductory; for a detailed

treatment of this topic, including a suggested checklist of specific items, see the *ACS Safety Audit/Inspection Manual* available at membership.acs.org/ccs/pubs/safety.pdf (accessed Aug. 26, 2005).

A safety audit is a systematic review of operations intended to ensure that what should be done is, in fact, being done, both in spirit and to the letter. A safety audit has two parts: acquiring information and then evaluating it. Several governmental regulations identify the details of the information to be acquired: OSHA regulations, particularly in 29 CFR 1910 but elsewhere in 29 CFR as well; EPA regulations in 40 CFR; DOT regulations in 49 CFR; and corresponding state and local regulations. Details can also be found in company policies and rules.

A safety audit should reveal current defects and weaknesses in the operation of a company facility; however, perhaps more important, it should also identify its strengths. Audit data are acquired by reviewing records and procedures, identifying records that should be available but are not, and conducting interviews. Data are collected from management and operations. Too often, in these latter collections, maintenance and janitorial operations are overlooked. Remember to review the mailroom, the shipping department, and the personnel in other service operations.

A proper safety inspection is a monitoring function with a positive purpose: to identify existing and potential accident-causing hazards, actions, and failures to act, which, once identified, can be corrected. Safety inspections are usually conducted by teams, not by the safety committee. The team gives copies of its report to the safety committee, which is responsible to top management. At least one member of the inspection team should have some knowledge of safety principles. Equally important is the presence on the team or committee of a person with practical knowledge that has been obtained from personal work experience; a janitor, a maintenance person, or a facility manager could fill this role.

Safety inspections are time-consuming; it is often practical to inspect only a limited area for safety one week-for example, electrical safety-and to cover another area, perhaps the frequency of toxic exposures, or hazards of a physical nature, on a following week. Guided by the decisions of an active committee, eventually the entire company will be thoroughly safety-inspected by one team or another-and then the time will come to begin all over again.

6.6 Employee Training

Employee training is required under the Hazard Communication Standard and under the Laboratory Standard. The following comments may be helpful in designing and implementing a training program.

The purpose of training is to help employees perform tasks safely when they work with chemicals. When proper precautions are taken, hazardous chemicals cannot cause harm. These precautions must be learned because they are not obvious to an untrained person. Common experience teaches that a sharp knife can cut, so most people know to exercise care when using this tool. But the dangers of many chemicals are not as obvious. Phenol, for example, has killed careless workers; n-hexane has caused permanent peripheral neuropathy; and borax has caused long-lasting respiratory disease. Although phenol has a somewhat

unpleasant odor, the odor of hexane is considered by many to be almost pleasant, and borax is a white, innocent-appearing powder. To an untrained person, none of these three indicate the severity of the hazards they present. Only workers who know the hazards and how to take the proper precautions can be assured of safety from the harm that these three, or any other chemical, can cause when used improperly. It is essential for employees to be trained in the hazards and appropriate precautions for the chemicals they will use.

The MSDS for a chemical is a useful source of information. It identifies the hazards and describes the precautions to be taken. However, because of the style in which it is written, an MSDS is not a suitable source of information for most employees. It must be interpreted for them. Training can change employee behavior, and during training, employees will have the MSDSs for the chemicals they use explained to them. Other sources of information include the label on the container and a variety of reference works, such as those identified in Appendix I. There are many ways to conduct the training, such as the following:

- a. Lecturing in a classroom-like environment
- b. Telling small groups or single employees about the hazards and precautions in the work area
- c. Showing employees how to handle a hazardous chemical by personal example
- d. Preparing a videotape that demonstrates in detail how to handle a hazardous chemical in the employee's workplace
- e. Using purchased or prepared presentations and audio/visual material for training

Frequent and very brief, informal reviews of what has been learned can be combined with new or changed information. No single way is best for everyone, and usually a variety of techniques is the most effective.

Evaluation of the effectiveness of the training is the final step in the process. Because the purpose of safety training is to insure proper employee behavior, safety training can be evaluated by observing an employee's behavior in handling hazardous chemicals. When incorrect procedures are noticed, they should be corrected as soon as possible. Avoid describing corrections in terms of errors by the worker. The trainer may not have explained the correct procedure clearly or the trainee may not have understood the training.

Retraining will be necessary, perhaps every 6 to 12 months. If employees are not performing chemical handling satisfactorily, the training program should be reevaluated, planned, and conducted more effectively.

Training records should be signed, should describe the content and date of each training session, and should identify the trainees. These records should be kept permanently.

6.7 OSHA and EPA Requirements

Two OSHA regulations have been discussed in Section 6.6. Many other OSHA regulations, all found in 29 CFR, are applicable to small chemical businesses. Some of these are not well-known and are identified here; the section identification refers to the section, or subpart, of 29 CFR:

- a. The employer's safety and health protection policy must be posted. See Section 1903.2(a)(1).
- b. Employers must maintain a log and summary of occupational injuries and illnesses on OSHA Form 200. There are posting requirements and records that must be retained. See Section 1904.
- c. A written emergency action plan and a written fire protection plan must be prepared. See Sections 1910.38(a) and 1910.38(b).
- d. Portable fire extinguishers must be inspected monthly. See Section 1910.156(d). Hands-on training in the use of fire extinguishers must be provided annually for employees whose job requires the use of fire extinguishers. See Section 1910.157(g).
- e. Safety shower and eyewash facilities must meet the requirements of Section 1910.151(c). See also ANSI Z358.1.
- f. Respirators must be inspected, and records must be maintained. See Section 1910.134.

In addition to the requirement for an emergency coordinator, other EPA requirements include plans for spill prevention; controls and countermeasures for fires, explosions, or accidental releases; and hazardous waste management. Details are given in 40 CFR 265.50-265.56 and 265.112.

SARA Title III, the Community Right-to-Know Act, addresses emergency planning and emissions of hazardous materials, and it introduces the Toxic Release Inventory Form. This report requires an evaluation, or "mass balance" accounting and reporting, of specific chemicals manufactured or used in the workplace above certain threshold levels. Copies of 29 CFR and 40 CFR should be obtained from the U.S. Government Printing Office and studied thoroughly. Further information can be obtained from the regional OSHA and EPA offices. Refer to Appendices II and III.

A number of states have regulations that require written plans or other reports. Check with the state authorities or agencies for information. Regional OSHA and EPA offices will be able to direct you appropriately.

7. AMERICANS WITH DISABILITIES ACT

The federal ADA prohibits employment discrimination against a qualified person with a disability. This covers private employers with 25 or more employees after July 26, 1992; the act is enforced by the Equal Employment Opportunity Commission (EEOC). Employees protected under the act are those who have a substantial impairment and are qualified to perform the essential duties of the job, with or without reasonable accommodation. The pertinent regulations are published in the *Federal Register*, July 26, 1991, and *A Guide to Disability Rights Laws*, available at www.usdoj.gov/crt/ada/cguide.htm (accessed March 13, 2007). EEOC has established a technical assistance program separate from its enforcement activities to help employers comply with the law. ADA resulted in new commercially available hood designs and new advances in laboratory design for

access by workers with disabilities.

The ACS Committee on Chemists with Disabilities (CWD) has published *Teaching Chemistry to Physically Handicapped Students*, with suggestions on training and evaluation of employees with physical disabilities. The March 1981 issue of the *Journal of Chemical Education* featured several articles on teaching chemistry and chemical safety to people with physical disabilities. Additional information can be found in the November 12, 2001, issue of *Chemical & Engineering News* in the article "Approaching a Workplace for All", which can be found at the CWD Web page under "ACS/CWD Publications": membership.acs.org/c/cwd/index.htm (accessed Aug. 26, 2005).

8. VISITORS

Visitors should be escorted at all times. While in laboratories, process areas, pilot plants, or manufacturing plants, visitors should wear safety glasses with side shields. Small children should not be allowed to enter a laboratory, warehouse, or plant where hazardous chemicals are being used or are available on open shelves.

9. SECURITY

An unfortunate development in recent history has been a higher level of concern about security issues in light of the increase in acts of terrorism. Hazardous materials at a small chemical business may become the target of terrorist action. Here are some issues to be reviewed by the staff:

- a. Evaluate access and egress to the facility, and identify any potential weak points (e.g., shipping and receiving areas, garbage and waste pickup zones, etc.).
- b. Does the facility have security cameras? Where are they located? Are they monitored? What type of security is there for the cameras?
- c. Do employees all have photo identification, and are they required to wear them? Are the photo badges color-coded for access to specific areas?
- d. Is there a perimeter fence? Is it secure? How is it guarded? Is it inspected on a regular basis?
- e. For smaller facilities with a skeleton staff on certain shifts, is there adequate security at entrance areas?
- f. What type of emergency communication is available in the event of an attack on the facility?
- g. What hazardous materials are present at the facility that are susceptible (fuels, flammable and corrosive materials), and is there extra security for those areas?
- h. What is the worst-case scenario in the event of (a) a terrorist attack, (b) vandalism, (c) violent weather, (d) a power failure, (e) a fire, and (f) a major release of hazardous material?
- i. What types of backup power are available?
- j. If you are hosting a meeting involving outside personnel, what are your specific

responsibilities? Do you know exactly who is coming? Do your guests know where they are allowed to go, and what are the limits on their movement through the facility?

- k. What evacuation procedures are in place in the event of an attack?
- l. What personal protective equipment is readily available in the event of an emergency?
- m. Who owns the surrounding property, and what is the access? Are there residential properties that might be vulnerable in the event your facility is attacked?
- n. What federal, state, and local agencies are available to assist you in case of an emergency? Do they know about the materials and activities at your facility?

PART II

Employee Guide to Safety

1. SAFE WORK PRACTICES

1.1 Introduction

Safe work practices require alertness and a knowledgeable awareness of potential hazards. The first and most important rule is this:

Do not use or handle any chemical until YOU have read and understand the label and the material safety data sheet (MSDS) for that chemical.

The second rule states that safety is the collective responsibility of everyone. It requires the full cooperation of all concerned. This means that each person must observe safety precautions and procedures and should do the following:

- a. Follow all safety instructions carefully.
- b. Become thoroughly acquainted with the location and use of safety facilities such as fire extinguishers, showers, exits, and eyewash fountains.
- c. Ensure that necessary safety equipment is readily available and in usable condition.
- d. Before undertaking any work, become familiar with the hazards of the chemicals being used and the safety precautions and emergency procedures.
- e. Before beginning an operation, become familiar with the chemical operations and all hazards involved, including the precautions both on the labels and on the MSDSs. In addition, pay attention to potentially hazardous reactions such as those described in *Bretherick's Handbook of Reactive Chemical Hazards*, sixth edition; the Letters column of *Chemical & Engineering News*; the American Chemical Society (ACS) Committee on Chemical Safety (CCS) website, membership.acs.org/c/ccs; and *NFPA 491M: Fire Protection Guide to Hazardous Materials*, 2001 edition, published by the National Fire Protection Association (NFPA).

Many accidents have resulted from an indifferent attitude, failure to use common sense, or failure to follow instructions. Be aware of what your co-workers are doing because you can be a victim of their mistakes. Do not hesitate to point out to other employees that they are engaging in unsafe practices or operations. If necessary, report unsafe practices or unsafe conditions to management.

Horseplay cannot be tolerated. Variations in procedures, including changes in quantities or reagents, may be dangerous. Never leave unattended a reaction that is in progress.

Anticipate sudden backing up or changes in direction from others. If you stumble or fall while carrying glassware or chemicals, try to project them away from yourself and others. Use a proper transport device, such as a rubber pail or a cart with side rails and secondary containment trays, for transporting chemicals and apparatuses. Shield chemicals and equipment from shock during any disruption of movement. Stairs must be negotiated carefully. Elevators, unless specifically indicated and so designated, should not be used for carrying chemicals. Do not smoke around chemicals and apparatuses in transit as well as inside or outside the work area itself.

1.2 Eye Protection

All persons in the work area, including visitors, must wear eye protection at all times, even when not performing a chemical operation. Safety glasses with side shields are the minimum recommended level of eye protection. Descriptions of suitable safety glasses and goggles are found in the current edition of the American National Standards Institute (ANSI) Z-87.1 standard. In many workplaces where hazardous chemicals are used or handled, the wearing of contact lenses is prohibited or discouraged. Contrary to the widely held belief that there are dangers associated with wearing contact lenses in an industrial chemical environment, there is no published evidence to support that belief. Because of the increasing use of contact lenses and the benefits they provide in improving vision, the CCS members, having studied and reviewed the issue, are of the consensus that contact lenses can be worn in most work environments, provided that the same approved eye protection is worn that is required of other workers in the area. It should be emphasized that contact lenses by themselves do not provide adequate protection in any environment in which there is a chance of an accidental chemical splash or exposure to harmful vapors. In addition, face shields that protect the neck and ears as well as the face, along with approved standing shields, should be available as appropriate for vacuum work or where there is a potential for explosions, implosions, or splashing. Face shields alone are not considered adequate eye protection and should always be worn in addition to safety goggles.

1.3 Clothing

To avoid exposure to hazardous materials, wear clothing that completely covers the torso and legs. Open-backed or sleeveless shirts, shorts, or short skirts are inappropriate apparel in a chemical workplace. Laboratory jackets or coats worn to protect clothing should be fastened only with snap fasteners so that they can be readily ripped off if necessary. Wash laboratory coats separately from personal laundry. Nonflammable, nonporous aprons are the most satisfactory.

Wear shoes that completely cover the feet. Do not wear high-heeled shoes, open-toed shoes, open-backed shoes, sandals, or shoes made of woven material. Steel-tipped shoes should be worn where heavy objects or large equipment is handled. Inspect gloves for holes or tears before wearing them.

For your protection, neckties and jewelry (rings, bracelets, and watches) should not be worn in an industrial chemical workplace. Dangling neckties and jewelry can become entangled in equipment, and jewelry can conduct electricity. Chemicals can seep under jewelry and cause serious injury to the skin. Chemicals can ruin jewelry by changing its composition.

1.4 Food and Beverages

Do not prepare, store, or consume food or beverages in any chemical work area. Industrial chemicals must not be placed in refrigerators used for storing food and beverages. Never use laboratory glassware or apparatuses for eating or drinking purposes.

1.5 Smoking

Do not smoke inside or outside any chemical work area.

1.6 Personal Hygiene

The following basic work practices are essential:

- Before leaving any chemical work area, wash hands and arms thoroughly, even if gloves have been worn.
- Do not apply cosmetics in a chemical work area.
- Use only the respirator equipment that has been personally assigned for your use. Respirator training, medical certification, and fit testing are all required.
- Do not use a mouth suction when pipeting or for starting a siphon.
- If you must smell a chemical, gently waft the odor toward your nose using some type of fan or your hand. Do not place the container directly under your nose and inhale the chemical.

1.7 Unattended Operation of Equipment

Reactions that are left to run unattended overnight or at other times are prime sources of fires, floods, and explosions. Do not let equipment such as power stirrers, hot plates, heating mantles, and water condensers run overnight without fail-safe provisions and the consent of management. Check unattended reactions periodically. Always leave a note plainly posted with a phone number where you can be reached in case of an emergency. Remember that in the middle of the night, emergency personnel are entirely dependent on accurate instructions and information.

1.8 Working Alone

Do not work alone with chemicals. Work should be absolutely forbidden unless there are at least two people present.

1.9 Workers' Responsibility

Employees must learn, understand, and follow all safety rules and regulations that apply to their work areas. Workers must use personal protective equipment as appropriate for each procedure that involves hazardous materials. Workers have the responsibility to seek advice and guidance whenever they are in doubt about safety procedures or potential hazards in their work and to inform their supervisors of unsafe conditions. Workers must notify their supervisors immediately if they experience an injury or illness in the chemical workplace.

2. SAFETY TRAINING

2.1 Chemical Hazards Orientation

Employers are required to provide instructions regarding hazards of the chemicals being used and the manner in which these chemicals are to be handled and disposed of safely. The information provided by the container labels and by

the MSDSs, which are now required under the Occupational Safety & Health Administration (OSHA) Hazard Communication Standard as well as other local and state right-to-know laws, should be understood. Document all safety training. Additional information is available from the references provided in Appendix I.

2.2 Reading and Understanding a Material Safety Data Sheet

There is a specific list of items that are required to be on an MSDS. Each such item, with an explanation of its meaning, follows:

- a. **Chemical Name**—usually the IUPAC (International Union of Pure and Applied Chemistry) or Chemical Abstracts Service (CAS) chemical name is given, but it also may be a common name for the chemical (e.g., ethylene glycol is acceptable instead of 1,2-ethanediol). Trade names may be supplied, but the chemical name is also required unless it is considered a trade secret.
- b. **CAS Registry Number**—This number is not required by OSHA, but most state right-to-know laws require it. This number is assigned to each chemical by CAS. There are a few instances where a chemical has several different numbers. A few chemicals have no assigned number, and most mixtures do not have assigned numbers.
- c. **Date Prepared**—OSHA requires that the date of preparation or latest update be on the MSDS.
- d. **Composition of Mixtures**—This includes all hazardous materials in concentrations greater than 1% and all carcinogens in concentrations greater than 0.1%. Trade names can be used, but chemical names must also be included unless this information is considered a trade secret.
- e. **OSHA Permissible Exposure Limit (PEL)**—A time-weighted average limit for an 8-hour day and, for some chemicals, also includes a maximum concentration exposure limit. The figures may be in parts per million or milligrams per cubic meter.
- f. **American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV)**—An exposure limit, similar to the PEL, recommended by ACGIH. The measuring units specified in the OSHA PEL are applicable. The ACGIH TLV list is updated each year. TLVs are considered guidelines, not regulated exposure limits.
- g. **Health Effects**—This section identifies target organs or systems adversely affected by overexposure, as well as chronic effects and any existing condition that would be aggravated by exposure.
- h. **Physical and Chemical Characteristics**—This section usually includes the following items where applicable:
 - *Boiling point*—the value may be at reduced pressure and either in degrees Celsius or Fahrenheit.
 - *Melting point*.
 - *Vapor density*—relative to air.
 - *Vapor pressure*—usually in millimeters of Hg; the temperature must be specified (usually in the range of normal room temperature).
 - *Specific gravity*—density with respect to water at a specified temperature.

- *Solubility in water*—approximate values are acceptable.
- *Appearance and odor*.
- *Evaporation rate*—usually relative to butyl acetate.
- *Fire and Explosion Hazard Data*—This section usually includes the following items:
 - *Flash point*—the temperature at which vapors from a liquid can be ignited. Open or closed cup should be specified.
 - *Flammability limits*—lower and upper concentrations in air (percent) below and above which volatile flammable chemicals cannot be ignited.
 - *Auto-ignition temperature*—the minimum temperature at which a chemical ignites spontaneously in the air.
 - *Recommended extinguishing media*.
 - *Unusual fire and explosion hazards*.
- j. **Reactivity Hazard Data**—Information should include whether the material is unstable and under what conditions instability exists, incompatibilities, and whether hazardous decomposition products can be produced.
- k. **Health Hazard Data**—This topic includes one or more of the following:
 - *LD50 (Lethal Dose 50)*—the lethal single dose (usually oral), in milligrams of chemical per kilogram of animal body weight, that is expected to kill 50% of a test animal population. The animal should be specified. Because some animals react differently to some chemicals, this is not necessarily an indication of the hazard of the chemical to humans.
 - *LC50 (Lethal Concentration 50)*—a concentration dose, expressed as parts per million for gases and vapors or as micrograms of material per liter of air for dusts and mists, that is expected to kill 50% of a test animal population in one exposure.

In the Health Hazard Data Section of MSDSs, often words or phrases such as *avoid contact* and *flammable* are used. Generalized descriptions of many of these phrases and the precautions to be practiced follow. The general rule for all chemicals, even if they are considered nonhazardous, is to avoid contact.

ALLERGIC REACTION: Some individuals may develop severe allergic reactions to even undetectable quantities of certain types of chemicals (e.g., amines, organosulfur compounds).

PRECAUTIONS: For the susceptible individual, virtually total isolation from the chemical is necessary. Allergy studies by a qualified physician may be necessary.

CARCINOGEN: A substance that may possibly, is suspected to, or is known to cause cancer. Some may have threshold limits of exposure.

PRECAUTIONS: Exercise extreme care when handling! Do not breathe vapors, and avoid all contact with skin, eyes, and clothing by wearing suitable protective equipment and using appropriate confining apparatuses. OSHA has specific rules for handling known carcinogens. Refer to 29 CFR 1910, Subpart Z.

CORROSIVE: A chemical that destroys living tissue on contact and can cause a severe corrosion rate in steel or aluminum.

PRECAUTIONS: Do not breathe vapors, and avoid contact with skin, eyes, and clothing. Use suitable protective equipment.

DANGER: Applies to substances that have known harmful effects. Also applies to substances whose properties are unknown but that may have harmful effects, based on their similarity to compounds with known harmful effects.

PRECAUTIONS: Treat these chemicals as if these are the most dangerous chemicals that exist. There may or may not be serious hazards associated with them.

EXPLOSIVE: A substance known to explode under some conditions.

PRECAUTIONS: Avoid shock (dropping), friction, sparks, and heat. Isolate from other chemicals that become hazardous when spilled.

FLAMMABLE: A substance that gives off vapors that ignite easily and burn rapidly under usual working conditions; the flash point is less than 100 oF (140 oF for materials regulated by the U.S. Department of Transportation, or DOT).

PRECAUTIONS: Keep away from heat, sparks, or flames. Be aware that materials with a high vapor density tend to creep along the floor or ground until an ignition source is found. For more details, see Section 7.5.1.

HIGHLY REACTIVE: A substance that reacts vigorously with water, air, or any other substance to which it may be exposed in the working environment.

PRECAUTIONS: Use extreme care in opening and handling the substance. Examine the reactivity section of the MSDS for additional details.

IRRITANT: A substance that causes a reversible inflammatory effect on the skin, eyes, or respiratory tract.

PRECAUTIONS: Do not breathe vapors, and avoid contact with skin and eyes. The effect may be evident at an extremely low concentration.

LACHRYMATOR: A substance that has an irritant or burning effect on the skin, eyes, or respiratory tract. A lachrymator is dangerous in very small quantities. (Opening the cap has an immediate effect on eyes.) Causes tears upon exposure.

PRECAUTIONS: Only open in an operating, fully tested laboratory chemical hood! Do not breathe vapors. Avoid heating. Avoid contact with skin, eyes, and clothes.

MUTAGEN: A chemical or physical agent that causes genetic alterations.

PRECAUTIONS: Handle with extreme care! Do not breathe vapors, and avoid contact with skin, eyes, and clothing.

OXIDIZER: A substance capable of supplying its own source of oxygen or other

highly reactive material to a reaction.

PRECAUTIONS: Do not open or handle the material without thoroughly understanding the potential reactions that the substance can undergo. This information should be in the reactivity section of the MSDS.

PEROXIDE FORMER: A substance that forms peroxides or hydroperoxides upon standing or when in contact with air.

PRECAUTIONS: Many peroxides are explosive! Do not open bottle if a residue is present on the outside of the cap or inside the bottle! For more details, see Sections 7.1-7.3.

POISON: A substance that has very serious and often irreversible harmful effects on the body. Hazardous when breathed, swallowed, or in contact with the skin. In sufficient quantity, leads to death. DOT regulations classify many poisons for transportation.

PRECAUTIONS: Avoid all contact with the body. When handling, use suitable protective equipment.

STENCH: A foul smell that many substances have or generate.

PRECAUTIONS: If substances have a stench, open them only in a properly operating laboratory chemical hood equipped with an adequate absorbing system.

TERATOGEN: A substance that causes the production of physical defects in a developing fetus or embryo.

PRECAUTIONS: Handle with extreme care! Do not breathe vapors, and avoid contact with skin, eyes, and clothing. Use suitable protective equipment when handling.

TOXIC MATERIAL: A substance that is hazardous to health when breathed, swallowed, or in contact with the skin. Prolonged exposure brings the danger of serious damage to health.

PRECAUTIONS: Avoid all contact with the body. When handling, use suitable protective equipment.

- l. **First Aid**—Appropriate procedures for emergency first aid should be given in the MSDS, identifying antidotes, if known.
- m. **Precautions for Spills and Cleanup**—Appropriate steps for safe cleanup of a spill or release should be given. An appropriate waste disposal method, including whether the material can be put in a landfill or other Environmental Protection Agency (EPA)-approved disposal facility, should be supplied in the MSDS.
- n. **Control Measures**—Types of protective clothing, gloves, and respiratory protection should be listed. If the material should always be handled in a hood, in a glove box, or with extra ventilation, it should be listed under this heading.

- o. **Storage**—This section should indicate whether refrigeration or special storage conditions are necessary. It should also indicate incompatibilities in storage conditions.

2.3 Evacuation and Fire Drills

Every employee should be aware of the location of the fire exits, alarms (and their operation), and telephones. Emergency drills should be scheduled on a regular basis. Employees should be instructed to go to a prearranged place outside the danger area and remain in that place until accounted for.

2.4 Use of Fire Extinguishers

Every person should be aware of the location of fire extinguishers and should be given annual hands-on training in the proper manner of operating them. Any use of a fire extinguisher must be reported so the extinguisher can be refilled and replaced promptly.

2.5 Safety Showers and Eyewashes

Every person should know the location of the nearest safety shower and eyewash fountain and how to operate them.

3. EMERGENCY ACTION

3.1 Dealing with an Emergency

When an emergency occurs, determine the nature of the emergency, whether it is safe to remain on the scene, and whether somebody has been injured. The following steps should then be taken:

- a. Follow local procedures for initiating an emergency alarm.
- b. Report the nature and location of the emergency to the appropriate fire or medical facility; give your name, telephone number, and address. Tell where you will meet the emergency vehicle. If individuals are involved, report how many; whether they are unconscious, burned, or trapped; whether an explosion has occurred; and whether there is or has been a chemical or electrical fire.
- c. Tell others in the area about the nature of the emergency.
- d. Meet the ambulance or fire crews at the place you indicated. Send someone else if you cannot go.
- e. Do not make any other telephone calls unless they directly relate to the control of the emergency.

3.2 Protecting Life

Do what is necessary to protect life while waiting for assistance. Keep calm. The following suggestions are currently acceptable practices for emergency action:

- a. Do not move any injured persons unless they are in immediate danger from chemical exposure or fire. Keep them warm. Unnecessary movement can

severely complicate neck injuries and fractures.

- b. If chemicals have been spilled on a person, wash the affected area thoroughly (at least 15 minutes) using a safety shower, hose, or eyewash fountain as appropriate. See Sections 6.3 and 6.4 for full details.
- c. Use a blanket in shock cases and for the protection of an injured person from exposure en route to medical aid.
- d. If a person's clothing is on fire, use the safety shower. If the shower is not readily available, douse the individual with water. Get him or her to stop, drop, and roll; that is, to lie down and roll to put out the fire. Then try to extinguish any small flames by patting them out. Beat out the flames around the head and shoulders, then work down toward the feet. Next, cover the injured person with a coat, blanket, or whatever is available, but leave the head uncovered. Do not use fire blankets until the fire is extinguished. While wearing gloves if necessary, remove any clothing contaminated with chemicals. Use caution when removing pullover shirts or sweaters to prevent contamination of the eyes. It may be better to cut the garments off. Douse with water to remove heat, and place clean, wet, ice-packed cloths on burned areas. Wrap the injured person to avoid shock and exposure. Get medical attention promptly.
- e. If there is a fire and there is little personal risk, use the appropriate extinguisher if you have been trained in its proper use. If the fire is very small, it may be extinguished by smothering it with a nonflammable material such as an inverted beaker, watch glass, or metal sheet. Fight the fire from a position of escape. Understand that it is easy to underestimate a fire. Turn off electrical circuits and gas lines. Close fire doors. Do not use elevators to leave the building; use the stairs. Keep the lights on.
- f. Anyone overcome with smoke or fumes should be moved to uncontaminated air and treated for shock. Provide oxygen for inhalation, if possible.
- g. If hazardous chemicals are ingested, follow the first aid treatment shown on the label or the MSDS. Never give anything by mouth to an unconscious person. Determine exactly what substances were ingested, and inform the medical staff (while the injured person is en route to a hospital, if possible). The nearest poison control center can give advice.
- h. If the injured person is not breathing, the Red Cross recommends the following procedure: Place the person face up, clear the mouth of any obstruction, and loosen tight clothing. Lift the neck and tilt the head back so that the chin is pointing upward. Insert your thumb in the mouth, grasp the lower jaw, and lift it forcibly upward and forward. Pinch the nose and blow vigorously through the mouth to make the chest expand. Repeat every 4 to 5 seconds. If the injured person's chest does not expand, recheck the mouth for any obstruction, tilt the head back farther, and resume blowing into the mouth.
- i. If an individual is bleeding severely, the Red Cross recommends the following procedures: Control the bleeding by compressing the wound with a cloth or whatever is available. Elevate the injury above the level of the heart. If blood is spurting, place a pad directly on the cut and apply firm pressure. Wrap the

injured person to avoid shock, and get immediate medical attention. In the case of a less severe cut, wash the cut and remove any pieces of glass, wrap the injured person to avoid shock (except in the case of a trivial cut), and get medical attention. A pressure pad may be applied firmly on the wound. Pressure points should be tried before using tourniquets. Tourniquets should be used only by persons trained in first aid.

- j. Do not touch a person who is in contact with a live electrical circuit. Disconnect the power first or you may be seriously injured.

4. HANDLING CHEMICALS

4.1 General Precautions

All chemicals are potentially harmful. Avoid direct contact with any chemical. Some substances now considered “safe” may in the future be found to cause long-term disorders. It is especially important to keep chemicals from the hands; the face; and clothing, including shoes or other foot coverings. Many substances are readily absorbed into the body through the intact skin and through inhalation. Chemicals can also enter the body through the mouth by contamination of the hands, and chemicals can be transferred to the eyes from the hands. Therefore, the following precautions are recommended:

- a. Do not use or handle any chemical until you have read the label and you understand the hazards of that chemical.
- b. Keep your hands and face clean. Wash thoroughly with soap and warm water whenever a chemical contacts your skin. Always wash your hands and arms before leaving the work area.
- c. Never taste a chemical. If it is necessary to smell a chemical, cautiously waft the vapor toward the nose. Smoking, drinking, eating, or applying cosmetics is forbidden in chemical work or storage areas.
- d. Some solvents, such as dimethyl sulfoxide, serve as vehicles for the rapid transport of dissolved toxic substances through the skin into the body. Always wear suitable gloves when handling such materials.
- e. All containers of chemicals must be labeled clearly. Do not use any substance from an unlabeled or improperly labeled container.
- f. Safe handling and storage procedures for compressed gases are discussed in Section 5.9.

4.2 Safe Laboratory Techniques

There are a number of generally accepted laboratory techniques that will make working with chemicals safer. Some of these are discussed below.

- a. When opening bottles, hold the bottle with its label toward your palm to protect the label (and also the hand of the next user) in case some reagent drains down the side of the bottle. Stoppers that cannot stand upside down on the bench top should be held at the base and pointed outward between two fingers of the pouring hand. Do not pour toward yourself when adding liquids

or powders. Use a funnel if you are pouring into a small opening. If a stopper or lid is stuck, use extreme caution in opening the bottle.

- b. Always add a reagent slowly; never dump it in. Observe what happens when the first small amount is added, and wait a few moments before adding more; some reactions take time to start.
- c. Before pouring a liquid into an addition or separatory funnel, make sure the stopcock is closed, firmly seated, and freshly lubricated (if glass). Use a stirring rod to direct the flow of the liquid being poured. Keep a beaker under the funnel in the event the stopcock opens unexpectedly.
- d. To avoid a violent reaction and spattering while diluting solutions, always pour concentrated solutions slowly into water or into less concentrated solutions while stirring. The more concentrated solution is usually more dense, and any heat evolved is better distributed. This applies especially when preparing dilute acids. Always wear goggles and use the laboratory chemical hood when diluting concentrated solutions.
- e. Support a small beaker by holding it around the side with one hand. If the beaker is 500 mL or larger, support it from the bottom with the other hand, and consider using heavy-duty beakers. When setting the beaker down, first remove your hand from the base, and then place the beaker slowly on the clean surface of the bench. A small piece of grit can make a “star” crack in the thin, flat bottom of a beaker or flask. If the beaker is hot, use beaker forceps or heavy gloves and place the beaker on a ceramic-centered gauze pad.
- f. Grasp multinecked flasks by the center neck, never by one of the side necks. If the flask is round bottomed, it should rest on a proper-sized cork ring when it is not assembled for a reaction. Large flasks must always be supported at the base during use.
- g. Never look down the opening of a vessel.
- h. Never use mouth suction to fill a pipet. Use an aspirator bulb or a loose-fitting hose attached to an aspirator. Constantly watch the tip of the pipet, and do not allow it to draw air.
- i. Flasks and beakers containing hot or boiling liquids should always be cooled before any additional chemical is added.
- j. When carrying large bottles of corrosive, toxic, or flammable liquids, use impact-resistant transport containers.

4.3 Adequate Ventilation

Hazardous chemicals should be dispensed and handled only where there is adequate ventilation, such as in a hood or vented enclosure. A large number of common substances present acute respiratory hazards and should not be used on the open bench where dispersion into the surrounding air is possible. Adequate ventilation is defined as ventilation that is sufficient to prevent excessive exposure to those chemicals for which exposure values have been established. Chemical exposures should always be below the OSHA PEL, the ACGIH TLV, or the American Industrial Hygiene Association’s workplace environmental exposure level (WEEL).

If you smell a chemical, you are inhaling it. Also, remember that the vapors

of many chemicals can be at hazardous concentrations without any noticeable odor. The same applies to dusts, mists, and smokes. A chemical that has an odor may not be hazardous, aside from the nuisance of the odor.

Chemicals can be broken down by the body into hazardous metabolites. Similarly, byproducts of chemical reactions can be extremely hazardous. Planning for the handling and control of these toxic metabolites and byproducts should be part of the experimental procedure.

4.4 Separations

4.4.1 Extractions

Extractions can present a hazard because of the potential buildup of pressure from a volatile solvent and an immiscible aqueous phase. Glass separatory funnels used in laboratory operations are particularly susceptible to problems because their stoppers or stopcocks can be forced out, resulting in a spill of the contained liquid. It is even possible for pressure to burst the vessel. The following is an accepted procedure for accomplishing such a separation.

Do not attempt to extract a solution until it is cooler than the boiling point of the extractant. When a volatile solvent is used, the unstoppered separatory funnel should first be swirled to allow some solvent to vaporize and to expel some air. Close the funnel and invert it with the stopper held in place, and immediately open the stopcock to release more air plus vapor. This should be done with the stopcock handle and funnel drain turned away from you and others, with the hand encompassing the barrel to keep the stopcock plug securely seated. (Note: Glass stopcocks should be lubricated.) Do not vent the separatory funnel near a flame or other ignition source. Then close the stopcock, shake with a swirl, and immediately open the stopcock with the funnel in the inverted position to again vent the vapors. If it is necessary to use a separatory funnel larger than 1 L for an extraction with a volatile solvent, the force on the stopper may be too great and cause the stopper to be expelled. Consider performing the extraction in several smaller batches.

4.4.2 Distillations

Distillations are probably the most common method of separation and purification used in laboratory and industrial operations. Potential dangers arise from pressure buildup, the common use of flammable materials, and the necessity for heat to vaporize the chemicals involved. A variety of apparatus designs are used to accomplish distillations at atmospheric pressure, under inert atmospheres, at reduced pressure (vacuum distillation), and by the addition of steam to the distillation mixture (steam distillation).

Careful design and construction of the distillation system is required to accomplish effective separation and to avoid leaks that can lead to fires or contamination of the work area. It is necessary to ensure smooth boiling during the separation process and to avoid bumping, which can blow apart the distillation apparatus. Stirring the distillation mixture is the best method to avoid bumping. The use of boiling chips is effective for distillations carried out at atmospheric

pressure.

The source of heat is an important factor in the distillation process. Even heating can best be done by using an electric mantle heater, a ceramic cavity heater, steam coils, or a nonflammable liquid bath. Silicon oil or another suitable high-boiling oil can be used if heated on a hot plate. Hot water or steam may be used where practical. An additional thermometer may be inserted very near the center bottom of the distilling flask to warn of dangerous, exothermic decomposition. Always avoid heating above the temperature directed in the procedure.

Superheating and sudden boiling (bumping) frequently occur during distillation under reduced pressure. Therefore, it is important that the assembly be secure and the heat be distributed more evenly than is possible with a flame. Evacuate the assembly gradually to minimize the possibility of bumping. A standing shield should be in place for protection in the event of an implosion. Boiling chips are of little value in a distillation under reduced pressure. Liquids needing vacuum distillation are usually of high molecular weight and somewhat viscous at the distillation temperatures. Best results are obtained when the liquid being distilled is whipped into a fine spray of droplets using a motor-driven stirrer. This provides good vaporization without overheating and decomposition. After finishing a reduced-pressure distillation, cool the system before slowly bleeding in air, because air may induce an explosion in a hot system. Pure nitrogen is always preferred to air and can be used even before cooling the system. Refer to Section 5.8.2 for the safe use of cold traps during a vacuum distillation.

When carrying out a steam distillation, take care not to run the steam in at too great a rate for the condenser. Remember that the heat of condensation of steam is very high. Overfilling the flask is less likely if condensation from the entering steam line is trapped and if the flask is heated or insulated to prevent excessive condensation.

Organic compounds must never be distilled or evaporated to dryness unless they are known to be free of peroxides. Most ethers, including cyclic ethers, form dangerously explosive peroxides upon exposure to air and light. Unsaturated hydrocarbons, potassium metal, and other reagents can also form peroxides. See Sections 7.1-7.3 for further discussion.

4.5 Hazard Evaluation, Risk Assessment, and Hazardous Chemicals

A hazard is the danger that can result when an unwanted event occurs. Hazards are evaluated according to their potential, based on an analysis of their properties and their conditions necessary to produce an unwanted activity. Risk is a measure of the probability and the consequences of the hazards resulting from an activity or condition. Risk assessment is an evaluation of the probability that an undesirable event could happen and the extent of the impact it could have on the health and welfare of humans and the environment.

Chemicals often present biological, chemical, environmental, or physical hazards. A hazardous chemical or chemical mixture is one that can fit into one of three categories:

a. It has undesirable biological effects, either acute or chronic, depending on the

size and duration of the dose, the type of exposure, and the physical state of the material needed to produce such effects.

- b. Its toxicity information is not available, but the material is highly suspect because of its structural or functional similarity to known toxic agents.
- c. It is combustible, flammable, explosive, corrosive, or highly reactive.

Many organizations, such as OSHA, NFPA, EPA, DOT, have specific definitions for hazardous chemical classifications.

5. ASSEMBLING APPARATUSES

5.1 Working with Chemicals and Apparatuses

Following these recommendations will help make your work easier and equipment use safer:

- a. Plan your work before starting a procedure. Be sure you know what to do if you or another worker has an accident.
- b. Keep workspace free of clutter.
- c. Set up clean, dry apparatuses, firmly clamped and away from the edge of the bench. Be careful to place reagent bottles away from burners and other workers and their equipment. Choose sizes that can properly accommodate the operation to be performed, allowing at least 20% free space.
- d. Except for glass tubing, stirring rods, and graduated cylinders, use borosilicate glassware (e.g., Pyrex). Examine your glassware closely for flaws such as cracks and chips. Damaged glassware should be repaired (see your supervisor) or discarded in a properly labeled glassware waste container.
- e. All equipment should be free from flaws such as cracks, chips, frayed wire, and obvious defects. Check with your supervisor if you have questions.
- f. A properly placed pan under a reaction vessel or container will act as a secondary containment device to confine spilled liquids in the event of glass breakage.
- g. Use shields when working with reactive mixtures. Place the shields in suitable positions to protect yourself and others. Stabilize the shields with weights or fasteners so that they cannot be knocked over. Wear both eye and face protection when using shields.

When working with flammable gases or liquids:

- a. Do not allow burners or other ignition sources in the vicinity unless your supervisor directs otherwise.
- b. Use appropriate traps, condensers, or scrubbers to minimize release of material to the environment.
- c. If you will be using a hot plate or heating mantle, do not proceed with your work until you know the autoignition temperature of the chemicals likely to be released and can ensure that the temperatures of all exposed surfaces are less than those autoignition temperatures.
- d. Make certain that the temperature-control device and the stirring and

ventilating motors (if present) do not spark.

- e. Whenever possible, use an enclosed, nonsparking electric heater or hot plate or use steam in place of a gas burner. Use only nonsparking motors (e.g., air motors) in the work area when flammables are present.
- f. Support and orient large separatory funnels so that the stopcock will not be loosened by gravity. Use retainer rings on the stopcock plugs.
- g. Use securely positioned clamps to support condensers; secure attached water hoses with wire or clamps.
- h. Secure stirrer motors and vessels firmly to maintain proper alignment. Magnetic stirring is preferable, except for viscous materials.
- i. Position an apparatus that is attached to a ring stand so that the center of gravity of the system is over the base and not to one side. Arrange the apparatus so that burners and baths can be removed quickly. Stands bearing heavy loads should be firmly attached to the bench top. Anchor equipment racks at both the top and the bottom.
- j. Never place any apparatuses, equipment, boxes (empty or filled), containers of chemicals, or any other objects on the floor.
- k. Never heat a closed container. Make sure the heating apparatus has a vent.
- l. Before you heat more than a few milliliters of a liquid in an unstirred vessel, add some boiling stones or a short glass tube with one end closed. If, as in some distillations, there is the possibility of a dangerous exothermic reaction or decomposition, use a thermometer during the procedure to monitor the temperature of the liquid. This will provide a warning and may allow time to remove the heat and apply external cooling.
- m. Use an appropriate gas trap whenever evolution of hazardous gases or fumes is possible.
- n. Chemical hoods are recommended for all operations in which toxic or flammable vapors are evolved. Most flammable vapors have a density greater than that of air and will settle on a bench top or floor, where they may diffuse to a distant burner or other ignition source and flash back. These vapors will roll out over astonishingly long distances, and any ignition can flash back to the source. However, once diluted with significant amounts of air, the vapors will move in air essentially as air itself.
- o. When working with quantities of flammable liquids or gases that are too great to be conveniently handled in an enclosed hood, make sure that the procedures to be carried out have been thoroughly reviewed by a competent safety expert.
- p. Use a hood when working with a system under reduced pressure (which may implode). Close the sash of the hood to provide a shield. Note that unless designed and built for the purpose, hoods are not to be relied on for protection in case of an explosion.

5.2 Preparation of Glass Tubing and Stoppers

To cut glass tubing, hold the tubing against a firm support and make one quick, firm stroke with a sharp triangular file or glass cutter, rocking the file to

extend the deep nick one-third around the circumference. Cover the tubing with cloth, and hold the tubing in both hands away from your body, with the nick centered between your hands and turned away from your body. Place your thumbs on the tubing opposite the nick about 1 in. apart and extended toward each other. Push out on the tubing with your thumbs as you pull the sections apart, but do not deliberately bend the glass with your hands. Avoid accidental contact of the tubing with a nearby person by standing with your back toward a wall or the lab bench. If the tubing does not readily pull apart, the nick probably is too shallow or rounded; make a fresh, sharp file scratch in the same place and repeat the operation. Be careful when cutting a short piece from a long piece of tubing, because the long end may whip and injure a nearby person.

All glass tubing and rods, including stirring rods, should be fire polished before use. Unpolished cut glass has a razorlike edge, which not only will lacerate the skin but will cut into a stopper or rubber hose, making it difficult to insert the glass properly. After polishing or bending glass, allow ample time for it to cool; then touch it gingerly before grasping it to be certain it is not too warm.

When drilling a stopper, use only a sharp borer that is one size smaller than what would just slip over the tube to be inserted. For rubber stoppers, lubricate with water or glycerol. Bore holes by slicing through the stopper, twisting with moderate forward pressure, grasping the stopper only with the fingers, and keeping the hand away from the back of the stopper. Keep the index finger of the drilling hand against the barrel of the borer and close to the stopper to stop the borer when it breaks through. Drill only partway through, and then finish by drilling from the opposite side. Discard a stopper if a hole is irregular or does not fit the inserted tube snugly, if it is cracked, or if it leaks.

When available, ground glassware is preferable. Glass stoppers and joints should be clean, dry, and lightly lubricated. Rubber or cork stoppers should fit so that one-third to one-half of the stopper is inserted into the joint. Corks should have been previously softened by rolling and kneading.

5.3 Insertion of Glass Tubes or Rods into Stoppers or Flexible Tubing

Frequently a short piece of metal tubing can be substituted for glass tubing. The following practices will help to prevent accidents:

- Make sure the diameter of the tube or rod is compatible with the diameter of the hose or stopper.
- Fire polish the end of the glass to be inserted.
- Lubricate the glass. Water may be sufficient; glycerol is a good lubricant.
- Wear leather gloves or wrap a cloth around the glass and protect the other hand by holding the hose or stopper with a cloth.
- Hold the glass not more than 5 cm from the end to be inserted.
- Insert the glass with a slight twisting motion, avoiding too much pressure and torque.
- A tube that has become stuck in a hose or stopper may be removed by slitting the hose or stopper with a sharp knife.

- Often a cork borer can be used as a sleeve for the insertion of glass tubes.

5.4 Glassware

Borosilicate glassware is recommended for all laboratory glassware except for special experiments that use UV or other light sources. The only soft glassware that should be used are some reagent bottles, measuring equipment, stirring rods, and tubing. Any sizable nonspherical glass equipment to be evacuated, such as suction flasks, should be specially designed with heavy walls. Dewar flasks and large vacuum vessels should be taped or otherwise screened or contained in a metal jacket to prevent flying glass caused by an implosion. Thermos bottles with thin walls are not adequate substitutes for Dewar flasks. Bottles, jars, and other containers of acids, alkalis, flammable or combustible substances, or corrosive chemicals should be transported in carriers to protect them from breakage, as well as to limit the spread in case of leaks. Note that even plastic containers can cause similar problems because plastic can be punctured, fail under pressure or heat, or crack as a result of age.

5.5 Working with Reduced Pressure

Protect vacuum desiccators by covering them with cloth-backed friction or duct tape or by enclosing them in a sturdy box or in an approved shielding device to restrict flying fragments in case of an implosion. Store only chemicals being dehydrated or protected from moisture in a desiccator. Before opening a desiccator that is under reduced pressure, make sure that atmospheric pressure has been restored. Occasionally, a vacuum desiccator lid will be found to be frozen after atmospheric pressure has been restored. Try using a single-edge razor blade as a wedge; tap it gently with a wooden block to loosen the lid.

Surround an apparatus that is under reduced pressure with shielding. If you use vacuum pumps, place a cold trap between the apparatus and the vacuum pump so that volatiles from a reaction or distillation neither mix with the pump oil nor escape into the atmosphere of the work area. When possible, vent exhausts from pumps to a properly functioning hood. Vacuum pumps with belt drives must be equipped with belt guards.

Water aspirators for reduced pressure are used for filtration purposes and for some rotary evaporations. Use only equipment that is approved for these purposes. For example, use only a heavy-walled filter flask designed for the purpose; never apply reduced pressure to other flat-bottomed flasks. When you use a water aspirator for reduced pressure, place a trap and a check valve between the aspirator and the apparatus so that water cannot be sucked back into the system if the water pressure should fall unexpectedly during filtering.

Superheating and consequent bumping (sudden boiling) frequently occur when you use reduced pressure for distilling. Therefore, it is important that the assembled apparatus is secure and that heat is distributed more evenly than is possible with a flame. Use a heating mantle whenever possible. Evacuate the assembly gradually to minimize the possibility of bumping. Stirring or using a nitrogen or other inert gas (never use air) bleed tube often can provide good

vaporization while preventing bumping or overheating and decomposition. Use standing shields to surround the apparatus for protection in the event of an implosion. After you finish a reduced-pressure distillation, allow the system to cool before slowly bleeding in air; the oxygen in air that is introduced into a hot apparatus may induce an explosion in the hot system. Pure nitrogen or another inert gas is preferable to air during distillation and for cooling the system.

5.6 Centrifuges

Bench-top centrifuges should be anchored securely so that if vibration occurs, they will not “walk” off the edge of the bench or knock over bottles and equipment. These rules apply to the safe operation of centrifuges:

- If vibration occurs, stop the centrifuge immediately and check the counterbalance load. If swing-out buckets are present, check them for clearance and support.
- Always close the centrifuge lid before operating the centrifuge; keep it closed while the centrifuge is running.
- Do not leave the centrifuge until full operating speed is attained and the machine appears to be running safely without vibration.
- If the centrifuge has no brake, allow the centrifuge to coast to a stop. If it has a brake, use the brake, not your hand, to stop the centrifuge.
- If requested by your supervisor, thoroughly clean the centrifuge and buckets regularly using a noncorrosive cleaning solution.

5.7 Oil and Sand Baths

When you use hot oil or sand for heating, take care to avoid hazardous spattering if water or an organic liquid falls into the hot oil or sand.

Avoid overheating an oil bath. Watch for smoking of the oil; oil that is smoking is too hot and may burst into flames at any moment. Do not leave an operating sand or oil bath unattended unless it is equipped with a high-temperature shutoff and a warning label (Hot Oil or Hot Sand).

Ensure that glassware that is to be used in an oil or sand bath is free of cracks and other imperfections. Do not use a sand or oil bath unless it is equipped with a thermometer or other temperature-indicating device. In addition, an oil bath must be labeled with the name of the oil and its maximum safe working temperature. Take precautions to contain any spills of hot oil or hot sand caused by breakage or overturning of the baths.

5.8 Cooling Baths, Cold Traps, and Temperature Control

5.8.1 Cooling Baths

When ice water is not cool enough as a bath or cold trap, salt and ice may be used. For lower temperatures, dry ice or dry ice with an organic liquid may be used. To be used safely with dry ice, an organic liquid should have the following five characteristics:

- Nontoxic vapor
- Low viscosity

- Nonflammability
- Low volatility
- Suitable freezing point

Acetone and butanone are volatile and flammable and should not be used. Isopar L, a mixture of long-chain isoparaffins that has a boiling point of 188 °C and a flash point of 60 °C, is an excellent substitute. When Isopar L is mixed with dry ice, temperatures of about -75 °C can be achieved. Therefore, Isopar L is suggested instead of acetone in combination with dry ice for cold traps and cooling baths.

The final choice of a liquid will also depend on the temperature requirements. Although no substance works in all situations, these liquids are suggested:

- Isopar L
- Ethylene glycol or propylene glycol in a 3:2 ratio with water and thinned with isopropyl alcohol (CAUTION: becomes viscous)
- Some glycol ethers (CAUTION: become viscous)
- Isopropyl alcohol (CAUTION: flammable)

Add the dry ice to the liquid, or the liquid to the dry ice, in small increments. Wait for the foaming to stop before proceeding with the addition. The rate of addition can be increased gradually as the liquid cools.

Do not lower your head into a dry ice chest. No oxygen is present, and suffocation can result. Do not handle dry ice with bare hands; if the skin is even slightly moist, a severe burn can result. Wear dry leather or suitable cryogloves, safety goggles, and a lab coat when handling dry ice.

5.8.2 Cold Traps

Cold traps that are used in reduced-pressure systems should be wrapped with cloth-backed friction tape or duct tape so that, in the event of an implosion, the tape will reduce flying glass. A better alternative is to place the cold trap in a vermiculite-filled metal can.

Special attention should be directed to the boiling points of the components and the possible products of materials in the system. Even an inert atmospheric gas must be considered. For example, argon, a common inert gas, has a boiling point of -186 °C, which is very close to that of liquid nitrogen (with a boiling point of -195 °C), a common coolant for cold traps. Argon is condensed into traps cooled with liquid nitrogen. When the cooling bath is removed, the argon rapidly vaporizes and the rate of pressure buildup may be too great to be vented or pumped down. A potentially dangerous explosion can occur.

Exercise caution when using liquid cryogenic coolants. Follow the precautions described in the MSDS for the cryogenic liquid you will be using. Be aware that very low temperature coolants, such as liquid nitrogen, will condense oxygen from the air upon standing and then cause an explosion if they come in contact with combustible materials. These precautions are essential:

- Wear gloves, a lab coat, and a face shield. Immerse the object to be cooled slowly to avoid too vigorous boiling and overflow of the coolant.
- Use only properly vented containers when handling cryogenic liquids.

- c. Glass Dewar flasks should be made of borosilicate glass. Protect them by covering them with cloth-backed friction tape or duct tape or by encasing them in a metal sheath to contain flying pieces in the event of an implosion.
- d. The edge of a glass Dewar flask is fragile. Avoid pouring cold liquid onto the edge of a glass Dewar flask when filling because the flask may break and implode. For the same reason, do not pour a cryogenic liquid out of a glass Dewar flask; use a siphon. Consider using a metal or plastic Dewar flask to eliminate this problem.
- e. Never use a household thermos bottle or other insulated container in place of a Dewar flask. Thermos bottles and other insulated containers are designed to keep consumable liquids cold; they are not sturdy enough for laboratory use.

5.8.3 Temperature Control

Many reactions must be initiated by heating. Because the rates of most chemical reactions increase as the temperature increases, highly exothermic reactions can become dangerously violent unless provisions are made for adequate cooling. Some exothermic reactions have an induction period. In such reactions, if too much reagent was added initially, the reaction can become too vigorous for effective condensation of vapors once the induction period is completed. A cooling bath must be prepared in advance and be ready to be applied promptly to the reaction vessel. Remember that viscous liquids transfer heat poorly and require special precautions.

Many reactions require some temperature control. Assemble your apparatus in such a way that both heating and cooling can be controlled—that is, readily applied and withdrawn. For example, when you are heating the contents of a test tube in a burner flame, it is easy to overheat the test tube and cause the contents to boil up and out. To prevent this, hold the test tube with a test tube holder and heat it gently along the side, not at the bottom. Or heat the contents of a test tube by placing it in a hot water bath. Never point a heated test tube toward yourself or any other person.

5.9 Compressed Gases

When ordering hazardous gases, consider factors such as handling and storage, eye and skin absorption, proper gas regulators, and chemical properties. The publications of the Compressed Gas Association and of major suppliers should be consulted before using compressed gases. The rules for proper use of compressed gases include the following:

- a. Handle cylinders of compressed gases as high-energy sources and therefore as potential explosives.
- b. Restrain cylinders of all sizes, empty or full, individually by straps, chains, or a suitable stand to prevent them from falling.
- c. Store cylinders in appropriately ventilated cabinets or in an open storage area.
- d. When storing or moving cylinders, secure the protective caps in place over the valves in order to protect the valve stems.
- e. When moving cylinders, use only properly designed wheeled carts, and before

- moving, strap the cylinders securely in place on the cart.
- f. Do not expose cylinders to temperatures higher than about 50 °C. The rupture devices on some cylinders will release at about 65 °C. Some small cylinders, such as lecture bottles, are not fitted with rupture devices and may explode if exposed to high temperatures.
- g. Never use cylinders if their contents cannot be identified positively.
- h. Never lubricate, modify, force, or tamper with cylinder valves.
- i. Use toxic, flammable, or reactive gases only in laboratory hoods that are known to be operating properly.
- j. Never direct compressed air or high-pressure gases at a person.
- k. Do not use compressed gas or compressed air to blow away dust or dirt; the resultant flying particles are dangerous.
- l. Be aware that rapid release of a compressed gas will cause an unsecured gas hose to whip around dangerously.
- m. Rapid release of a compressed gas builds up a static charge that could ignite the gas if it is flammable or combustible.
- n. Do not extinguish a flame involving a highly combustible or flammable gas until the source of gas has been shut off; otherwise, it can reignite and burn or even explode.
- o. Close main cylinder valves tightly when they are not in use.
- p. Promptly remove the regulators from empty cylinders, and replace the protective caps at once. Label the cylinder to show that it is empty.
- q. Never bleed cylinders completely. Leave a slight pressure to keep out contaminants.
- r. Use the appropriate regulator on each gas cylinder. The threads on the regulators are designed to prevent improper use. Adapters and homemade modifications can be dangerous. Do not use them.
- s. Do not put oil or grease on the high-pressure side of a cylinder of oxygen, chlorine, or any other gaseous oxidizing agent. A fire or explosion can result. Never put oil or grease in, on, or near a regulator for the same reason.
- t. Always wear safety glasses or goggles when handling and using compressed gases.
- u. Observe the following special rules when working with acetylene cylinders:
 - Always store acetylene cylinders upright. They are partially filled with liquid acetone, which can be discharged instead of or along with acetylene if the cylinder is not upright.
 - Do not use an acetylene cylinder that has been stored or handled in a non-upright position until it has remained in an upright position for at least 30 minutes.
 - Ensure that the outlet line of an acetylene cylinder is protected with a flash arrester.
 - Never exceed the pressure limit indicated by the warning red line of an acetylene pressure gauge. Acetylene polymerizes rapidly and spontaneously when under “red line pressures”. The polymerization reaction is rapid, violent, and exothermic.

- Use the correct kind of non-cuprous tubing to transport gaseous acetylene. Tubing made of copper or high-copper brass will form copper acetylides, which are explosively unstable and shock- and impact-sensitive.

6. CHEMICAL SPILLS

6.1 General Procedures

The following steps are generally applicable:

- Immediately alert fellow workers and the supervisor.
- For all spills, all contaminated clothing must be removed immediately and the skin washed with soap and water. Flush the skin with water for no less than 15 minutes. Clothes must be laundered before reuse. (Do not wash with other clothing.) See also Section 6.3.
- If there is no fire hazard and the material is not particularly volatile or toxic, proceed to clean it up as directed in the MSDS. To facilitate cleaning up liquids, use an absorbent material that will neutralize the liquids if possible (trisodium phosphate, sand followed by sodium bicarbonate solution or powder for acids, sodium thiosulfate solution for bromine, etc.). Various commercial absorbents packaged individually (spill kits) or in bulk are available. Vermiculite and clay absorbents such as cat litter can be more economical substitutes, but they will not control hazardous vapors. Dry sand is even less effective. A dustpan and brush should be used, and protective gloves should be worn. While wearing gloves, clean the contaminated area with soap and water and mop it dry. If the spill is on the floor, some absorbent should be sprinkled on the spot to prevent slipping. Dispose of the residue properly. CAUTION: Vermiculite and some other absorbents create a slipping hazard when wet.
- If a volatile, flammable, or toxic material is spilled, immediately warn everyone to extinguish flames and turn off spark-producing equipment such as brush-type motors. Shut down all equipment, and vacate the area until it is decontaminated. The supervisor or management will be responsible for designating the extent of evacuation and the proper cleanup procedure. Avoid skin contact and, to prevent inhalation, wear an appropriate breathing apparatus. Clothing contaminated by spills or splashes should be removed immediately to prevent skin penetration.
- Many small liquid spills (less than 100 mL) can be absorbed with paper towels, sand, or an absorbent. However, paper towels can increase the surface area and evaporation, increasing the fire hazard. Most solid spills can be brushed up and disposed of in appropriate solid-waste containers, but care must be exercised to avoid reactive combinations. Don't leave paper towels or other materials used to clean up a spill in open trash cans in the work area. Dispose of them properly.

6.2 Spills of Specific Types of Chemicals

- Acids and other acid materials.* Use calcined absorbent products, such as Oil-Dri

or Zorball. Avoid contact with skin.

- Mercury.* Because of the high toxicity of mercury vapor, spilled mercury should be immediately and thoroughly cleaned up using an aspirator bulb or a vacuum device. If a mercury cleanup unit is available, become familiar with its location and proper use. Mercury spilled into floor cracks can be made nonvolatile by amalgamation with zinc dust. Domestic vacuum cleaners must not be used because they will only redisperse mercury aerosols and spread the contamination. A mercury vapor monitoring instrument should be available for determining the effectiveness of the cleanup.
- Alkali metals.* A spill of an alkali metal should be smothered with powdered graphite or Met-L-X extinguisher and moved to a safe location where it can be disposed of by reaction with a long-chain primary alcohol (n-butyl alcohol is acceptable). Sodium-potassium alloys (NaK) present even greater hazards than either sodium or potassium alone; observe the suppliers' recommendations strictly. Particles of alkali metal splattered on the skin should be rapidly removed, and the skin should be flushed quickly with water. If any metal on the skin becomes ignited, deluge it with cold water immediately.
- White (yellow) phosphorus.* A spill of white (yellow) phosphorus should be blanketed with wet sand or wet absorbent and disposed of by controlled burning outdoors, but first consult the regulations. If any white phosphorus is splattered on the skin, flush the skin with cold water and remove any adhering phosphorus.

6.3 Chemicals on the Skin

For spills covering small amounts of skin, immediately flush with water for no less than 15 minutes. If there is no visible burn, wash with warm water and soap, removing jewelry to facilitate removal of any residual materials. Check the MSDS to see if delayed effects should be expected. If a delayed reaction is noted, seek medical attention immediately and explain carefully what chemicals were involved.

For larger spills, quickly remove all contaminated clothing, shoes, jewelry, etc., while using the safety shower. Do not attempt to wash chemicals off clothing. Instead, remove the clothing. Seconds count, and no time should be wasted because of modesty. Be careful not to spread the chemical on the skin or especially into the eyes. Unless the eyes are affected, do not remove safety goggles until all chemicals are washed from the hair and face. Use caution when removing pullover shirts or sweaters to prevent contamination of the eyes. It may be better to cut the garments off. Immediately flood the affected body area with tempered water for at least 15 minutes. Resume if pain returns. Do not use creams, lotions, or salves. Get medical attention as soon as possible.

6.4 Chemicals in the Eyes

For chemical splashes, at least a 15-minute flush is recommended. Immediately flush the eyes with a copious amount of water under gentle pressure, checking for and removing contact lenses at once. However, contact lenses may

be difficult to remove, and the essential irrigation must not be delayed. Forcibly hold the eyes open to wash thoroughly behind the eyelids. Eyeballs should be rotated so that all surfaces are rinsed. In the absence of some type of eyewash device, the injured person should be placed on his or her back and water gently poured into the eyes. The injured eyes must be held open. After flushing, the injured person must be given prompt medical attention, regardless of the severity (or apparent lack of severity) of the injury. Keep the eyes immobilized with clean, wet, soft, cold pads while transporting the injured to medical attention.

6.5 Releases of Acutely Toxic Vapors and Gases

Some vapors and gases can be permanently disabling or lethal when inhaled even at low concentrations. These include the following:

- a. Fluorine
- b. Chlorine
- c. Bromine
- d. Iodine
- e. Phosgene
- f. Hydrogen cyanide and other cyanides
- g. Hydrogen sulfide
- h. Hydrogen selenide
- i. Hydrogen fluoride
- j. Arsine
- k. Stibine
- l. Phosphorus trichloride
- m. Phosphorus oxychloride
- n. Phosphorus tribromide
- o. Methyl isocyanate

If you plan to work with any of these chemicals, you should not only consult the MSDS but seek additional guidance on evacuation steps, first aid, and handling procedures before you begin working with the chemical.

7. SOME OTHER HAZARDOUS CHEMICALS

7.1 Inorganic Peroxides

Peroxides all contain the -OO- group; hydroperoxides, the -OOH group. Inorganic peroxides are known for the alkali metals, calcium, strontium, and barium. Such compounds are generally stable, but they produce hydrogen peroxide when reacted with water or dilute acids. When in contact with organic compounds, inorganic peroxides will form carbonate. Inorganic peroxides must be stored, handled, and used with caution. Peroxides of alkali metals are not sensitive to shock but are decomposed by moisture. The most common inorganic peroxides are sodium peroxide (Na_2O_2), hydrogen peroxide, sodium perborate, and sodium persulfate ($\text{Na}_2\text{S}_2\text{O}_7$).

Small spills of inorganic peroxides can be reacted cautiously with aqueous

sodium bisulfite (NaHSO_3) solution; larger spills should be absorbed with inert solids such as vermiculite, sand, or salt and then reacted with sodium bisulfite in a safe area. Skin that has been burned by these peroxides should be washed gently but thoroughly, and the injured person should be given prompt medical attention.

7.2 Organic Peroxides and Hydroperoxides

7.2.1 General Considerations

Most organic peroxides, R-O-O-R, and hydroperoxides, R-O-O-H, are unstable to some degree and can be difficult to handle. The hazard is greater with short-chain (low-carbon-number) peroxides. Many lower molecular weight peroxides can explode violently.

Organic peroxides and hydroperoxides are sensitive to heat, mechanical shock, friction, impact, and contact with oxidizing and reducing agents. All organic peroxides are flammable, and fires involving bulk quantities should be approached with extreme caution. Peroxides can burn vigorously, and putting out such fires is difficult. Even peroxides of moderate flammability can present fire hazards because they decompose to form highly flammable products. The oxygen formed by peroxide decomposition supports the ignition.

Organic peroxides are generally more stable when water is present to lower the shock and heat sensitivity of the peroxide. For example, benzoyl peroxide is a solid (with a melting point of 104-106 °C) that can ignite or explode from heat, impact, or friction, and that must be kept moist in storage. Unscrewing a container that has dry benzoyl peroxide or other peroxide crystals caught in the lid threads can cause the entire contents of the container to explode. Keep on hand no more than a short-term supply of any peroxide, and check the container at regular intervals. If in doubt, call an expert for disposal of these dangerous chemicals.

The following precautions should be followed when handling organic peroxides and hydroperoxides:

- a. Study and follow all precautions specified by the manufacturer of the substance before using it.
- b. Store the peroxides at the minimum safe temperatures to minimize the rate of decomposition. CAUTION: Do not refrigerate liquid or solutions of peroxides at or below the temperature at which the peroxides freeze or precipitate. Peroxides in these forms are extra sensitive to shock and heat.
- c. Limit the quantity of peroxide handled to the minimum amount required. Do not return unused peroxide to the container.
- d. Clean up all spills immediately using the procedures recommended in the MSDS. The first step is usually to dilute or disperse the peroxide with an inert substance.
- e. Remember that the sensitivity of most peroxides to shock and heat can be reduced by dilution with inert solvents such as aliphatic hydrocarbons (e.g., mineral oil) but NEVER with acetone or other oxidizable materials.
- f. Avoid using solutions of peroxides in volatile solvents when it is possible that the solvent will vaporize and thereby increase the peroxide concentration.
- g. Never use a metal spatula with organic peroxides. Contamination by metals

- can cause explosive decomposition. Use ceramic or plastic spatulas instead.
- h. Do not permit smoking, open flames, sparking equipment, or any other source of intense heat near peroxides.
 - i. Avoid friction, grinding, and all forms of impact, especially with solid organic peroxides. NEVER use glass containers with screw-cap lids or glass stoppers. Instead, use plastic (e.g., polyethylene) bottles and sealers.
 - j. Because peroxides are generally irritants, avoid ingestion, inhalation, and skin contact. Flush with water. Treat any areas of contact for burns, and get medical attention.

7.2.2 Disposal of Organic Peroxides

CAUTION: Only an expert or a bomb squad should dispose of highly concentrated peroxides of 25 g or more.

- a. Disposal of smaller quantities of peroxides can be done by diluting with water or another inert substance to a concentration of 2% or less and then transferring the mixture to a polyethylene disposal vessel containing an aqueous solution of a reducing agent (e.g., sodium bisulfite or acidified ferrous sulfate). Stir the mixture gently, then vigorously to complete the chemical reaction. Do not mix the resultant material with other waste chemicals for disposal. Spilled peroxides should be absorbed on vermiculite as quickly as possible. The mixture may then be burned directly or may be stirred with a suitable solvent to form a slurry that can be treated according to company procedures. Never flush organic peroxides down the drain.
- b. Large quantities (more than 25 g) of dilute peroxide solutions may require expert assistance. Consider each case individually for handling, storage, and disposal. Refer to the manufacturer's recommendations, and comply with applicable regulations.

7.3 Peroxide-Forming Compounds

7.3.1 General Considerations

Peroxide-forming compounds react with oxygen even at low concentrations and ordinary temperatures to form peroxide compounds that are usually hydroperoxides. In addition to any other hazards that they have, they pose a "peroxide threat", especially if the oxygenated product crystallizes when the material is cooled or becomes concentrated by evaporation or distillation of the unoxidized part. Peroxide crystals may form on the ground glass or other surfaces of a sealing plug or within the threads of a cap. Removing the plug, unscrewing, or otherwise removing the cap has caused detonations with serious, and in some cases fatal, consequences.

There are four main groups that are known to be peroxide-forming compounds:

- a. Ethers with primary and/or secondary alkyl groups, including open-chain and cyclic ethers, acetals, and ketals
- b. Hydrocarbons with allylic, benzylic, or propargylic hydrogens
- c. Conjugated dienes, enynes, and diynes

- d. Saturated hydrocarbons with exposed tertiary hydrogens

Some specific and typical examples are diethyl ether, diisopropyl ether, tetrahydrofuran (THF), *p*-dioxane, cyclohexene, isopropylbenzene (cumene), tetrahydronaphthalene (tetralin), divinylacetylene, decahydronaphthalene, and 2,5-dimethylhexane.

Peroxide-forming compounds cannot form peroxide or hydroperoxide compounds without exposure to oxygen or other oxidizers. Therefore, their containers should always be tightly sealed. Air should always be flushed out of the free space with an inert gas (usually nitrogen) before sealing. Plastic caps, stoppers, and plugs should be used to reduce corrosion and friction.

Peroxidation is generally a problem of the liquid state. Solid peroxide-forming compounds present little problem except when finely divided because the reaction, if any, will occur only at the surface. Peroxidation seems to be no problem within gases and vapors. For liquids, the peroxidation typically occurs when containers are not completely sealed and "blanketed" with inert gas. Breathing then occurs with changes in temperature and barometric pressure, and oxygen gets into the containers. Peroxide buildup is usually slow because the exchange of air is usually slow.

If abundant oxygen is supplied to a fast peroxide-forming compound, typically there is an induction period, followed by a relatively fast accumulation of hydroperoxide, which tapers off at a maximum level. Then the concentration stabilizes or even decreases because the hydroperoxide itself undergoes decomposition, forming byproducts such as alcohols and water that interfere with the free-radical chain reaction of peroxidation. The byproduct content may continue to grow, but the peroxide content does not. CAUTION: This scenario does not apply when peroxides separate in solid form. Then the peroxide is undiluted by solvents or byproducts and is an immediate threat.

7.3.2 Detection and Determination of Peroxides

A test for peroxides should only be attempted if it is clear that no danger will result from moving or opening the container. Solids observed in the liquid or around the cap can indicate dangerous peroxide buildup. The presence of most peroxy compounds, including all hydroperoxides, can be detected by the following test: Mix 1-3 mL of the liquid to be tested with an equal volume of glacial acetic acid in a test tube, add a few drops of 5% aqueous potassium iodide solution, and shake. The appearance of a yellow-to-brown color indicates the presence of peroxide. If the color is faint, run a blank to make sure the test is really positive. A semiquantitative testing kit using treated paper strips is available from chemical suppliers. Quantitative titration procedures are known.

However, in order to test for the presence of peroxide in a peroxide-forming compound, it is necessary to open the container. Test peroxide-forming compounds for the presence of peroxide immediately on receipt from the supplier, and repeat the testing frequently. If the peroxide test is positive, take the appropriate steps; if negative, record the date and the result (e.g., on a tag or label affixed to the container) and return the container to its proper place in storage.

7.3.3 Some Uncommon Peroxy Compounds

Expect surprises when dealing with peroxy compounds. Two paraffinic hydrocarbons, 2,5-dimethylhexane and 2,6-dimethylheptane, have been found to deposit crystalline dihydroperoxides upon long exposure to air. The liquid phase always contains a low concentration of the corresponding monohydroperoxide. Caution is recommended.

1,4-Cyclohexadiene has been found to react with oxygen and generate hydrogen peroxide. When exposed to air, the clear liquid becomes cloudy and slowly forms a bottom layer that proves to be hydrogen peroxide in 60-80% concentration. This is capable of inflicting severe burns. Dilution or washing with water easily removes the immediate hazard. An organic hydroperoxide is formed, but it immediately decomposes into hydrogen peroxide and benzene. Some alkyl derivatives of this hydrocarbon behave similarly.

Most ketones, especially when they are water-free and exposed to sunlight, can peroxidize slowly. They form peroxides rapidly when in contact with peroxy reagents. Acetone can form an explosive crystalline peroxide when treated with hydrogen peroxide. Other ketones may yield peroxides, which may not be crystalline products, by similar treatment. Do not mix peroxy compounds with ketones unless literature reports or cautious experiments prove that the exact procedure is safe.

Follow these precautions for storing and handling peroxide-forming compounds:

- a. Label the chemicals as peroxide-forming or (in some cases) as possible peroxide-forming materials.
- b. In laboratory use, limit the stock of any item to a supply of 3 months or less, and discard the remaining stock unless it is found to be essentially peroxide-free.
- c. In plant use, monitor drum and tank supplies at regular intervals (1-3 months). If peroxide starts to accumulate, use the lot promptly only if the peroxide level is considered safe. If not within safe limits, destroy or remove the peroxide.
- d. In both laboratory and plant storage, always maintain an inert atmosphere (nitrogen or argon) in the "free" space of each container. Either flush with a stream of the gas or use pressure siphoning with the gas when withdrawals are made.
- e. Unless it would compromise the material's usefulness, add an oxidation inhibitor to it. The recommended amount is from 0.001 to 0.01% of inhibitors such as hydroquinone, 4-tertiary-butylcatechol (TBC), or 2,6-ditertiary-4-methylphenol (BHT).
- f. Before distilling any known or suspected peroxide-forming compound, check it carefully for peroxide. If any is present, eliminate it by chemical treatment or percolation through a suitable adsorbent, or add a high-boiling aliphatic hydrocarbon (such as mineral oil) to prevent the peroxide from concentrating to a dangerous level. Never distill a peroxide-forming material to dryness.

7.4 Perchloric Acid

Under some very specific conditions, perchloric acid is a powerful oxidizing agent that may react explosively with organic compounds and other reducing agents. Room temperature perchloric acid solutions can oxidize at concentrations above 73%. When heated to temperatures greater than 60 oC, perchloric acid begins to exhibit oxidizing potential at concentrations of about 50%. Under these conditions, perchloric acid must be used only in a water wash-down laboratory chemical hood of noncombustible construction. Frequent inspections should be made to prevent perchloric acid and perchlorate accumulation in the exhaust system of the hood. Do not use perchloric acid around wooden tables or benches. Keep perchloric acid bottles on glass or ceramic trays that have enough volume to hold all the acid, should the bottle break. Organic matter should be digested with nitric acid before the addition of perchloric acid. Never heat perchloric acid with sulfuric acid because dehydration may produce anhydrous perchloric acid. Transition-metal perchlorates are capable of exploding.

7.5 Solvents

Many of the commonly used solvents are volatile and can be harmful even upon exposure to relatively small amounts. Some are readily absorbed through the skin. Most are flammable or combustible. Organic solvents should be regarded as potentially hazardous unless definitely known to be innocuous.

7.5.1 Flammable Liquids

A flammable liquid itself does not burn; it is the vapor from the liquid that burns. The vapors are often denser than air. The vapors can travel long distances and also accumulate in pits and other low areas. The vaporization rate increases as the temperature increases; therefore, a flammable liquid is more hazardous at elevated temperatures than at normal temperatures. Minimize fire and explosion hazards associated with flammable liquids by observing the following precautions:

- a. Keep flammable liquids away from heat, direct sunlight, and sources of static electrical charge. See Section 11.2.
- b. Do not heat flammable liquids directly over a flame or other source of heat that can generate sparks or that has a surface temperature approaching the autoignition temperature of the liquid.
- c. Before using equipment that produces a spark, a flame, or a hot surface (e.g., motors, hot plates, and open heaters), verify that no flammable vapors are present. The turning on of a light, a timer, or an actuated relay switch-or the ringing of a telephone-can ignite flammable vapors, even when the source of the vapor, a flammable liquid, is not nearby.
- d. Do not dispose of flammable liquids in sinks or drains.
- e. Use a laboratory chemical hood or equivalent ventilation when appreciable quantities of flammable materials are transferred from one container to another, allowed to stand in open containers, or heated in open containers.

7.5.2 Toxicity of Solvents

The toxicity of common solvents must be recognized. Some common solvents that require special care are the following:

- Benzene
- Carbon disulfide
- Glycol esters and glycol ethers
- Halogenated hydrocarbons
- Nitrogen bases, such as amines

Many halogenated hydrocarbons are suspected human carcinogens. Avoid exposure to the liquids and their vapors. High concentrations in the air also can rapidly lead to death from respiratory failure. Less severe exposure can lead to kidney and liver damage. Halogenated hydrocarbons can also be absorbed through the skin.

Benzene is a human carcinogen. Chronic poisoning can occur by inhalation of relatively small amounts of benzene over a long period of time. The toxic action is primarily on the blood-forming organs. Contact with the skin should be avoided because of potential skin absorption. Also, like other solvents, benzene causes dryness and cracking of the skin, which opens the way to infection and allergic responses. Benzene is also a flammable solvent and should be handled and disposed of with extreme care in accordance with all prevailing regulations. Whenever possible, toluene or xylene should be substituted for benzene.

7.6 Cryogenic Hazards

Cryogenic conditions are generally agreed to include the temperature range from the temperature of dry ice downward to temperatures approaching absolute zero. All cryogenic liquids are liquefied gases. The liquefied gases combine the hazards of flammability, reactivity, corrosivity, toxicity, and asphyxiation, and they vigorously support combustion. Even liquid nitrogen, ordinarily considered to be chemically inert, will condense oxygen from the air when allowed to stand exposed in an open container. The resulting liquid mixture should be handled as though it is as hazardous as pure liquid oxygen.

For example, when either liquid oxygen or oxygen-contaminated liquid nitrogen is spilled on a flammable or combustible solid (e.g., clothing, asphalt, wood), the oxygen, now a gas, tends to remain on and around the surface of the solid for several hours. If a source of energy (e.g., an ignition source) is brought near, a violent explosion can occur. Thus, asphalt on which liquid oxygen has recently been spilled can explode violently when struck with a hammer.

Follow these necessary precautions:

- Know the first aid procedures for frostbite before using, handling, or storing a cryogenic liquid.
- Keep flammables and combustibles well away from liquefied oxidizing gases. For example, under suitable conditions, steel burns when in liquid oxygen.
- Avoid pouring a cryogenic liquid into a household thermos bottle or other insulated container ordinarily used to keep food or drinks cold.
- When using, handling, or storing cryogenic liquids, wear a laboratory coat

without outside pockets or wear a laboratory apron. Wear cuffless pants and high-topped leather shoes to deflect any spills; the bottoms of the pants should cover the tops of the shoes. Do not wear watches, rings, and other jewelry.

- The eyes are particularly vulnerable to harm from exposure to cryogenic liquids. Wear both safety goggles (Type G, H, or K) and a Type N face shield when working with cryogenic liquids.
- If it is necessary to handle chilled parts of the apparatus, consider wearing insulating gloves. If the gloves become contaminated with an oxidizing cryogenic liquid, handle the gloves as though they are flammable for at least 24 hours.
- Avoid skin contact with cryogenic liquids. Even very brief contact can result in severe frostbite and/or torn flesh.
- Employees who use, handle, or store toxic cryogenic liquids and all co-workers in the area should wear appropriate respiratory equipment.
- Avoid inhaling air that has been cooled to near-cryogenic temperatures.
- The chilled vapors from evaporated cryogenic liquids tend to accumulate in pits and low-lying areas. These gases are invisible and have partially or completely displaced oxygen from the area they occupy. Do not enter such areas without wearing an oxygen-supplying respirator.
- Never transport cryogenic liquids in an elevator. In the event of elevator malfunction, the resulting collection of evaporated gas in the elevator shaft from the cryogenic liquid could displace oxygen in the elevator. Even a so-called Dewar has a pressure-relief valve that can release evaporating vapors.
- Many solids become brittle and fragile at cryogenic temperatures. Before allowing an unfamiliar solid to be chilled to cryogenic temperatures, learn its properties at such temperatures.
- Immediately evacuate any area in which there is an uncontrolled release of a cryogenic liquid or vapor.

For more information, see ACS's Handbook of Chemical Health and Safety and the Compressed Gas Association's CGA P-12, Safe Handling of Cryogenic Liquids.

8. HOUSEKEEPING AND DISPOSAL OF LABORATORY WASTES

8.1 Housekeeping

In the laboratory and elsewhere, keeping things clean and neat generally leads to a safer environment. Avoid unnecessary hazards by keeping drawers and cabinets closed while you are working. Never store materials, especially chemicals, on the floor—even temporarily. Workspaces and storage areas should be kept clear of broken glassware, leftover chemicals, and even scraps of paper. Do not store chemicals in the laboratory chemical hoods. Keep aisles and paths of egress free of obstructions such as chairs, boxes, and waste receptacles. Do not block access to emergency equipment or utilities. Do not use hallways and stairs as storage spaces. Avoid slipping hazards by keeping the floor clear of ice, stoppers, glass

beads, glass rods, other small items, and spilled liquids. Use the required procedures for the proper disposal of chemical and other wastes.

8.2 Cleaning Glassware

Clean glassware at the laboratory sink or in laboratory dishwashers. Use hot water, if available, and soap or another detergent and mild scouring powder, if necessary. Wear impervious gloves that have been checked to ensure that no holes are present. Use brushes of suitable stiffness and size. Avoid accumulating too many articles in the cleanup area. Usually the workspace around a sink is limited, and piling up dirty or cleaned glassware leads to breakage. Remember that the turbid water in a sink may hide a jagged edge on a piece of broken glassware that was intact when put into the water. A pair of loose-fitting, coarse leather gloves may be useful for removing broken glass, but care must be exercised to prevent glove contamination. To minimize breakage of glassware, use sinks with rubber or plastic mats on their bottoms but not over the drains.

Avoid the use of chemical cleaning agents such as nitric acid, chromic acid, sulfuric acid, strong oxidizers, or any chemical with a "per" in its name (such as perchloric acid, ammonium persulfate, etc.) unless specifically instructed to do so, and then only when wearing proper protective equipment. A number of explosions involving strong oxidizing cleaning solutions, such as chromic-sulfuric acid mixtures, have been reported. The use of flammable solvents should be minimal, and when they are used, appropriate precautions must be observed.

8.3 Laboratory Storage of Chemicals

All chemicals should be labeled properly and dated upon receipt. Peroxide-forming chemicals should have the date the container was first opened on the label. Do not expose chemicals to direct sunlight or heat. Store toxic materials in a secure cabinet. Do not store chemicals on the floor or inside hoods. Laboratory storage of large containers of reagents should be kept to a minimum. They should be placed on a low shelf, preferably in a tray adequate to contain spills or leakage. Incompatible materials should not be stored together or in close proximity. See the list of incompatible chemicals in Appendix VI. Water-reactive chemicals should not be stored near a water source such as a faucet or sprinkler. Corrosives should never be stored above chin level. Safety cans must be provided for 1-gal or larger quantities of flammable solvents. If chemical purity requirements preclude the use of metal containers, an alternative is to place the glass container inside a metal container.

8.4 Disposal of Chemicals

Careless disposal can cause problems. Incompatible chemicals that are inadvertently mixed together on a bench or put into the same disposal container can produce toxic gases, catch fire spontaneously, or explode. Solid or liquid chemicals put into the sink drain can harm the environment. Broken glass in a wastepaper basket can injure the person who empties that basket.

Promote safety by following these commonsense practices when disposing of

chemical wastes:

- a. To minimize disposal problems, always specify the smallest amount that will suffice when ordering chemicals.
- b. Obtain directions for disposal from the supervisor.
- c. Do not let surplus chemicals accumulate indefinitely; if there is no likelihood of their use within the facility, they should be designated for disposal.
- d. When disposing of chemicals, one basic principle applies: Keep each different class of waste chemical in a separate disposal container.

Put ordinary wastepaper in a wastepaper basket separate from the chemical wastes. If a piece of paper is contaminated, such as paper toweling used to clean up a spill, put the contaminated paper in the special container that is marked for this use. It must be treated as a chemical waste.

Broken glass belongs in its own marked waste container. Place broken plastic apparatuses in a different marked waste container. Broken thermometers may contain mercury in the fragments, and these belong in their own special "broken thermometer" container. See Section 6.2 for instructions on cleaning up mercury spills from broken thermometers.

For leftover and unused chemicals, put each solid and liquid in its own specially marked container, based on hazard class compatibility, and close the container. Never deliberately put solid chemicals into the sink or down a drain. If it happens accidentally, notify your supervisor. CAUTION: Liquid chemicals may be put down the drain only if they are clearly nonhazardous or if permission is secured from the sewer authority. Flammable materials should never be poured down the drain.

9. SAFETY EQUIPMENT AND CLOTHING

9.1 Safety Showers and Eyewash Fountains

Safety showers and eyewash fountains should be located at least 5 feet apart. Often an employee who needs either of these facilities also will need help from one or two co-workers. If an accident involves two injured people, one who needs the shower and the other the eyewash, it would be very difficult to use both facilities properly if they were closer than 5 feet.

The water supply lines to eyewashes and safety showers should be valve-free in order to supply an uninterrupted water flow. If it is necessary to install a shutoff valve, a lock should be attached to keep the valve in the open position, with a tag affixed stating that the valve must be kept open during normal operation of the facility.

All employees must know the locations of the safety showers and how to operate them. Each work area where hazardous chemicals are used should be equipped with at least one safety shower. ANSI Z358.1 requires that safety showers be located no more than 10 seconds from any location in the room. The shower area must be kept clear of obstructions and be clearly labeled by highly visible signage on the wall. Chain pulls to activate the shower should be provided with a

large ring. The valve should open readily when the chain is pulled and remain open until intentionally closed. Water flow must be sufficient to drench the subject rapidly. ANSI Z358.1 requires a 30-gal/minute minimum flow of potable water. Provide temperate water for all safety showers; it is impossible to remain under a drenching shower for 15 minutes if the water is cold. Although a nearby floor drain is desirable, its absence should not prohibit installation of a safety shower.

The ANSI standard requires that safety showers be activated weekly to ensure that they are working properly. Keep a record of such tests, for example, on a tag affixed to the shower plumbing.

ANSI Z358.1 mandates a minimum 3-gal/minute water flow for handheld drench hoses and states that, although drench hoses are well-adapted for flushing when a safety shower or eyewash fountain cannot be used to flush a hazardous chemical from the eyes or skin, drench hoses are not a substitute for safety showers or eyewash fountains. When drench hoses are installed in a work area, every employee should know their locations, their limitations, and how to operate them. When feasible, employees should practice the procedure.

Employees should also know the locations of the eyewash fountains and how to operate them. Eyewash fountains should provide a copious and gentle flow of temperate, aerated, potable water at 0.4 gal/minute for a period of at least 15 minutes. Plumbed installations are strongly recommended. Use of the hands should not be required to maintain the water flow.

Small, handheld, portable eyewash units cannot provide a supply of water sufficient to copiously flush two eyes for at least 15 minutes. Also, the small units, the multigallon portable units, and the nonplumbed wall-mounted units provide an environment for the growth of microorganisms. All require strict attention in order to maintain sterility of the contained water. The small bottle-sized units should not be used. The use of multigallon portable units and nonplumbed wall-mounted units is strongly discouraged unless the sterility of the contents can be ensured and testing shows that a unit will flush both eyes simultaneously and will deliver at least 0.4 gal/minute of temperate water for at least 15 minutes.

As with safety showers, ANSI Z358.1 requires that eyewashes be flushed weekly. Such flushing reduces the risk of eye infections from contaminated standing water. Keep a record of these test flushes (e.g., on a tag affixed to the eyewash fountain plumbing). ANSI Z358.1 requires that eyewash units be located no more than 10 seconds from any workstations.

Always follow up every first aid treatment for the eyes with proper treatment by a member of the company's medical staff or an ophthalmologist who is qualified to treat chemical injuries to the eyes. Finally, all employees should understand that proper eye protection is much more effective than eyewashes in preventing eye injuries.

9.2 Fire Extinguishers

Fire extinguishers in the workplace should be a convenient size for rapid use and should be the appropriate type for the expected fire emergency. There should be at least one extinguisher easily accessible to each work area. Extinguishers must

be recharged promptly after use and should be sealed and clearly marked to ensure their utility. At least one large backup fire extinguisher of the dry chemical powder type should be conveniently located. Dry chemical fire extinguishers may be preferred for certain areas, but carbon dioxide is satisfactory for most small fires (with the notable exception of fires from alkali, alkaline earth, and certain other metals) and is cleaner to use around most equipment. Conventional dry chemical extinguishers expel a stream of sodium or potassium bicarbonate or other powder and are not recommended for Class A fires (wood, paper). Multipurpose dry chemical extinguishers release a stream of monoammonium phosphate as the extinguishing agent and are often preferred. Under OSHA rules, a person not trained in the use of fire extinguishers is prohibited from using them.

9.3 Laboratory Chemical Hoods (Formerly Called Fume Hoods)

Laboratory chemical hoods control hazardous chemicals (e.g., toxic, offensive, flammable, or reactive vapors). Apparatuses used in hoods should be fitted with condensers, traps, or scrubbers to contain or collect hazardous effluents. The hood should never be used as a means for disposing of chemicals.

The effective operation of a hood depends on many factors, including the face airflow velocity, the overall ventilation pattern of the room, the adequacy of the room air supply, and the methods of working at the hood. Before each use, be sure that the hood exhaust system is functioning properly. Adequate airflow and the absence of excessive turbulence are necessary for safe operation. All work in a hood should be carried out at least 15 cm (6 in.) from the front edge of the hood. A yellow line 15 cm from the edge can serve to indicate the limit of usage. Ensure that equipment does not block the hood baffles. It may be necessary to place large pieces of equipment on 2-in. blocks to permit adequate and uniform airflow.

Always keep your head outside of the hood face. Specialized vented workstations, such as vented balance safety enclosures, are available for many operations like weighing, microscopy, and pipeting. Flexible ductwork (or "elephant trunk") hoods should be used over the exit ports of equipment like gas chromatographs and atomic absorption spectrometers to remove toxic effluents from the work environment.

Hoods should never be used for the storage of chemicals. Chemicals should be stored in appropriate locations, as described in Part I, Section 4.8. Remember that in the event of an accident or fire, every item in the hood may be involved, including chemicals that are improperly stored in the hood.

9.4 Refrigerators

Storage of chemicals in refrigerators constitutes a unique hazard because the various control switches and defroster heaters can spark and ignite flammable materials. Explosions and fires may occur. Refrigerators used for low-temperature storage of industrial chemicals should be labeled for such use and must be explosion-proof. Never use household refrigerators for chemical storage. Most household refrigerators can be modified by a trained technician to remove internal sources of spark. However, the motor and other electrical parts on the exterior of

a modified household refrigerator can still ignite flammable vapors that are leaking out of the refrigerator or vapors that are already present in the room. In explosion-proof refrigerators, the internal wiring has been modified to eliminate ignition sources and the external motor and switches are sealed.

Industrial chemicals stored in refrigerators should be placed on a spill tray with edges sufficiently high to contain the spilled contents of any containers that are placed in the tray. Always seal and, if possible, double-package all chemicals to be stored in refrigerators; label each container legibly with the name of the material, the date placed in the refrigerator, and the name of the person who stored the material. Dispose of old chemicals after a specified storage period.

Store radioactive materials only in a designated refrigerator that can be locked and is properly labeled for such storage.

Never under any circumstances store food or beverages in a refrigerator that is used for industrial or laboratory chemicals or radioactive materials. Store food and beverages in a refrigerator that is labeled "Food and Beverages Only". Locate the food and beverage refrigerators in areas outside of the chemical laboratory or plant.

9.5 Gloves

Gloves are an important part of personal protection. They may be required for certain procedures. Gloves come in a variety of materials: latex, nitrile, neoprene, butyl rubber, and many others. Different types of gloves have different gauntlet lengths; some cover the entire arm, some cover the forearm, and some are only wrist-length. Although cloth or leather gloves may protect against hot or cold objects, do not rely on them for protection against hazardous chemicals. Cloth gloves are porous; leather gloves may be contaminated from prior use.

Use gloves correctly. Always check gloves before each use to ensure the absence of cracks and small holes. To avoid unintentionally spreading chemicals, remove your gloves before leaving the work area and before handling telephones, doorknobs, writing instruments, computers, laboratory notebooks, and reference books.

Be aware that no glove material can provide permanent protection. Eventually, liquids will permeate the glove. When certain glove materials are used with some liquids, permeation can take only a few minutes. Because the permeability of gloves made of the same or a similar material can vary by manufacturer, refer to the information provided by the manufacturer of the gloves for specific guidance. Use gloves only under the conditions and with the chemicals for which they are intended. If a chemical diffuses through a glove, that chemical is held against your skin; you could receive more exposure than if you had not worn a glove at all.

If gloves are clean, they may be reused. Do not reuse gloves if they previously have been permeated by a harmful chemical; they cannot be reused safely because the chemical cannot be totally removed. Gloves permeated by a hazardous material are themselves hazardous waste material and must be properly disposed of via the institution's waste policies.

10. FIRES AND EXPLOSIONS

10.1 Fires

The best way to fight a fire is to prevent it. You can prevent fires and reduce their severity considerably through proper housekeeping and thoughtful reflection about what you are doing. Proper housekeeping includes the following:

- Maintaining unobstructed aisles and exits
- Storing only limited quantities of flammable material
- Promptly disposing of waste
- Separating flammable liquids from combustible materials, such as cardboard boxes and paper towels

Stand back, take a look, and ask these questions:

- Are there any frayed wires?
- Is a stirrer with a sparking motor being used to stir a flammable liquid?
- Are bottles too close to the edge of the bench?
- Is the workspace cluttered?
- Do I understand each of the potential hazards in what I am about to do?
- Am I prepared in advance to take preventive steps?

If a fire occurs, the following actions are recommended:

- A fire contained in a small vessel can often be suffocated. For example, use a watch glass to suffocate a fire in a beaker by covering the mouth of the beaker. Do not pick up a vessel that is on fire. Do not cover it with dry towels or cloth; use a wet material. Remove nearby flammable materials to avoid spreading the fire.
- Activate the fire alarm. Notify co-workers and your supervisor. Call the fire department.
- If the fire is burning over an area too large for the fire to be suffocated quickly and simply, everyone should evacuate the area except those trained and equipped to fight fires. Use the stairs to leave the building; do not use the elevators. Follow evacuation procedures that have been established and that you have practiced during prior fire drills.
- It is easy to underestimate a fire. Never attempt to use a fire extinguisher unless you have been trained in its use and know that it is likely to extinguish the fire. If you have been trained in the use of a fire extinguisher, position yourself between the fire and an escape route (e.g., a door) and fight the fire from this location, but be sure that you can escape. Small fires that have just started often can be extinguished, but not always. If not extinguished, a fire can quickly threaten your life and those of your co-workers.

When a person's clothing is on fire, you may need to lead him or her to the safety shower. Some people instinctively run randomly if their clothes are on fire, which fans the flames and increases their injuries. If possible, stop an individual from running.

If the shower is not readily available, douse the individual with water. Get him or her to stop, drop, and roll; that is, to lie down and roll to put out the fire. Then try to extinguish any small, still-burning flames by patting them out. Beat out the flames around the head and shoulders, and then work downward toward the feet. Next, cover the injured person with a coat, blanket, or whatever is available, but leave the head uncovered. Do not use fire blankets until the fire is extinguished. While wearing gloves, if necessary, remove any clothing contaminated with chemicals. To prevent contamination of the eyes, use scissors when removing pullover shirts or sweaters. Wrap the injured person to avoid shock and exposure. Get medical attention promptly.

10.2 Runaway Reactions

A sudden, rapid rise in the temperature of a liquid that is being heated is evidence of a reaction that may become violent. Immediately remove heat, stop adding reagents, alert all persons nearby, and quickly move away. Do not return until the temperature has dropped to a safe level. Advanced knowledge of the reaction and the reaction potential will decrease hazards from these situations.

10.3 Explosions

Explosions result from the rapid expansion or evolution of gases, often in a closed or restricted system. One should ensure that a system has sufficient venting capability, including plenty of blowout panels. If the nature of the process involves a particular danger of explosion, always use adequate shielding and other appropriate safety devices. Special monitoring devices may also be advisable. Particularly dangerous reactions should be carried out in isolated areas, often using remote controls.

Employees in industrial laboratories or plants do not ordinarily work with very many substances that are explosive. Picric acid is rarely used; other nitrated organic compounds are used only occasionally. Perchloric acid is rarely used for oxidations involved in analytical work or other oxidative procedures. Organic peroxides (e.g., benzoyl peroxide) might be used now and then as polymerization initiators. Occasionally, unstable compounds (e.g., diazo derivatives) are used in some research projects, but this is rare.

These functional groups pose an explosion hazard: azide, ozonide, nitro, nitroso, diazo, halogen-substituted amine, and peroxide.

Some unstable compounds explode in the presence of a catalyst; others tend to explode at high temperatures. Some mixtures are shock-sensitive and will explode if impacted. Examples include carbon disulfide and potassium perchlorate; aluminum dust, magnesium dust, and sodium nitrate; many diazo compounds; and some organic nitrates.

Suspensions of oxidizable dust (e.g., magnesium, sulfur, or aluminum) in the air explode when ignited by a static electrical spark, flame, or other ignition source.

Keep explosive substances and mixtures well away from co-workers. Both in use and in storage, keep such substances well-separated from other unstable compounds, flammables, and toxins. For explosion hazard information, refer to

the MSDS and *Bretherick's Handbook of Reactive Chemical Hazards*.

Distillation of peroxide formers presents an explosion hazard, even if tests indicate that no peroxide is present. When you conduct these distillations, always protect yourself with shielding on all sides and wear both a Type N face shield and Type G, H, or K safety goggles. Have a fire extinguisher ready, along with someone who has been trained to use it. Do not distill these liquids to dryness. Stop the distillation while there is a considerable amount of liquid remaining in the distillation flask.

If an ignition source is present, any flammable gas or vapor can explode when mixed in suitable proportion with air, oxygen, chlorine, or other gaseous oxidizers. Acetylene and hydrogen are particularly hazardous in this respect because of their very wide flammability limits. Liquid oxygen is particularly dangerous. Liquid nitrogen that has been standing open to the air for some time becomes a mixture of liquid nitrogen and oxygen, which is also particularly dangerous; see Section 7.6.

It is prudent to run reactions on the smallest scale possible. When an explosion is a possibility, use less than 1 g total of all materials involved. Wear a Type N face shield; Type G, H, or K safety goggles; and a buttoned-up, thick, quilted lab coat. Cover any glass apparatus with a fabric-not plastic-tape (e.g., use duct tape), and surround the work with shatterproof shielding. Do not rely on an ordinary hood to provide protection. If it is considered necessary to work with or produce more than 1 g of an explosive compound or mixture, the work should be performed in a setting that is designed for such potentially dangerous activities.

11. ELECTRICAL HAZARDS

11.1 Precautions for Using Electrical Equipment

Electrical currents of low amperage and voltage under certain circumstances may result in fatal shock. Voltages as low as 24-V alternating current (ac) can be dangerous and present a lethal threat. Comparably low-voltage direct current (dc) circuits do not normally present a hazard to human life, although severe burns are possible. The longer that contact with a live circuit lasts, the worse the damage, especially for burns. Follow these recommendations:

- Only individuals qualified by training or experience should maintain or repair electric or electronic equipment.
- Do not use electric wires as supports. Never pull on live wires.
- Immediately report any electrical failure or any evidence of equipment overheating.
- Inspect all electrical equipment periodically to be certain the insulation on the cords is not frizzled, tattered, cracked, or damaged. Inspect the plugs; make sure they are not bent or damaged. Make sure that only three-wire grounded, double-insulated, or isolated wiring is used for 110-115-V ac applications.

11.2 Static Electricity and Spark Hazards

When handling flammable liquids, you can obtain some protection from

static electricity and sparks by properly grounding and bonding containers and equipment. The risk of static charge buildup is increased under conditions of low humidity (e.g., cold weather). For details, refer to NFPA 77: Recommended Practice on Static Electricity.

Common potential sources of electrical sparks and electrostatic discharges include the following:

- a. Ungrounded metal tanks and containers
- b. Clothing or containers made of plastic or synthetic materials
- c. An electric circuit that is made or broken while the circuit, or part of it, is energized
- d. Exposed hot nichrome wires (e.g., in hot air dryers, damaged heating mantles)
- e. Temperature-control systems and brush/commutator motors in some hot plates
- f. Discharge of gas from high-pressure gas cylinders
- g. Brush/commutator motors, often used in hot air dryers, stirrer motors, and air-moving fans

12. RADIATION HAZARDS

12.1 Radioactive Materials

Before you start any work, check with your state or federal agency (Nuclear Regulatory Commission) to determine which regulations regarding radioactive materials apply to your company. Coordinate all work requiring the use of radioactive materials with the person responsible for the laboratory or plant and under the direction of the company's radiation safety officer. Clearly label all radioactive materials, the vessels in which they are used, and the work area itself as a radioactive material use area. Always have the appropriate radiation measurement equipment in good working order while working with radioactive materials.

Anyone considering the use of radioactive materials should consult the radiation safety officer for advice on the regulations concerning procurement, handling, and disposal. All contaminated materials must be thoroughly cleaned or properly disposed of. These materials ordinarily would include glassware, wipes, gloves, spill pads, thin-layer chromatography (TLC) plates, pipets, and so forth. All employees planning to work with radioactive materials must first be trained in their safe handling. Worker protection requires good practices, adequate supervision, and control of exposure levels.

The ALARA (as low as reasonably achievable) exposure premise must be the guiding principle behind all radioactive work. This requires that the exposure to radiation or radioactive materials be kept to a minimum and that any associated radiation doses be decreased by reducing duration, increasing distance, and providing shielding when possible. Personal exposure monitoring may be required for users of radioactive materials. Such monitoring includes personal film badges, bioassay testing, and other scanning methods. The company's radiation safety officer is responsible for providing appropriate guidance on personal monitoring.

12.2 X-ray Generators and Particle Accelerators

These instruments can be dangerous because of the radiation they generate and the high voltages produced by their power supplies. Follow all the regulations of the Nuclear Regulatory Commission, your state department of public health, and your local radiological health service. Post warning signs in the area and on or near the main power switch of the instrument.

12.3 Lasers

Where lasers are used, the company may be required to have a laser safety officer who is knowledgeable in evaluating and controlling laser hazards and who is authorized and responsible for supervising their safe operation. Lasers and laser systems must be classified (I-IV) and appropriately labeled in accordance with the current edition of ANSI Z136.1. Class I lasers are of low intensity and pose little or no risk of physiological harm. Under certain conditions, Class II lasers can cause eye injury in people who lack a normal eye-aversion response to bright light. Class III and IV lasers are high-powered and can do considerable physiological damage, especially to the eyes; a medical professional should review the use and operation of Class III and IV lasers. Even reflected beams from a Class III or IV laser can cause eye injury.

Higher power lasers present additional hazards. The power density of the beam can be sufficient to ignite combustible materials. The high voltages involved present shock hazards. Some of the dyes used in dye lasers are reproductive toxins or are carcinogenic.

Only authorized individuals with specific training should use lasers. Everyone should obey all warning signs posted at the entrances to laser areas.

12.4 Ultraviolet Lamps

The use of UV lamps presents two types of hazards: those inherent in the radiation itself and those associated with operation of the lamps.

All radiation of wavelengths shorter than 250 nm should be considered dangerous. Wear protective safety glasses or goggles with UV-absorbing lenses whenever the eyes may be accidentally exposed to light in this wavelength region. It is advisable to operate such UV irradiation systems only in a completely closed radiation box. Wear slacks and a long-sleeved shirt to protect your skin. Skin areas exposed to illumination from UV lamps can be painfully burned in a way that is similar to severe sunburn.

Mercury arc lamps should be adequately cooled and operated within an enclosure designed to prevent damage by explosion of glass fragments and leakage of mercury vapor; make sure that the lamp you use is so equipped.

Do not handle mercury arc lamps with your bare hands. Deposits of oils from your skin damage the outer glass surface. If these oily residues are not thoroughly removed, they will burn into the glass, causing localized buildup of heat during the operation of the lamp. The lamp may then overheat, and the outer envelope may crack.

At the end of the useful life of a mercury arc lamp, buildup of UV-absorbing films on the interior glass walls may cause the temperature to rise above the safe operating point. Therefore, make sure the running-time meter on the lamp works so that you can know the total time the lamp has been operated.

APPENDICES

APPENDIX I - SOURCES OF ADDITIONAL INFORMATION

Publications

All books, even the best ones, may rapidly become outdated after they are published. Readers must make continual efforts to update their knowledge in the quickly changing field of chemical safety. The titles in the following bibliography that are regularly updated are marked by an asterisk.

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American Chemical Society, 1155 Sixteenth St., N.W., Washington, DC 20036; Committee on Chemical Safety (membership.acs.org/c/ccs); Division of Chemical Health and Safety (membership.acs.org/c/chas); Chemical Health and Safety Referral Service (800-227-5558); www.chemistry.org.
American Chemistry Council (formerly Chemical Manufacturers Association), 1300 Wilson Blvd., Arlington, VA 22209. 703-741-5000; www.americanchemistry.com.
American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Dr., Cincinnati, OH 45240. 513-742-2020; www.acgih.org.
American Industrial Hygiene Association, 2700 Prosperity Ave., Suite 250, Fairfax, VA 22031. 703-849-8888; www.aiha.org.
American National Standards Institute, 1819 L St., N.W., 6th Floor, Washington, DC 20036. 202-293-8020; www.ansi.org.
ASTM International (formerly American Society for Testing and Materials), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959. 610-832-9585; www.astm.org.
Canadian Centre for Occupational Health and Safety, 135 Hunter St. East, Hamilton, Ontario, Canada L8N 1M5. 800-668-4284; www.ccohs.ca.
Chemical Abstracts Service, 2540 Olenangy River Rd., P.O. Box 3012, Columbus, OH 43210. 614-447-3600; www.cas.org.

Interactive Learning Paradigms Inc., 4905 Waynes Blvd., Lexington, KY 40513-1469. 859-396-5218; www.ilpi.com.

International Agency for Research on Cancer, 150 Cours Albert-Thomas, 69372 Lyon Cedex 08, France. +33 (0)4 72 73 84 85; www.iarc.fr.

Laboratory Safety Institute, 192 Worcester Rd., Natick, MA 01760. 508-647-1900; www.labsafety.org.

MSDS Online, 350 North Orleans, Suite 950, Chicago, IL 60654. 888-362-2007; www.msds-online.com.

National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471. 617-770-3000; www.nfpa.org.

National Institute for Occupational Safety and Health (NIOSH), Hubert H. Humphrey Bldg., 200 Independence Ave., S.W., Room 715H, Washington, DC 20201. 800-356-4674; www.cdc.gov/niosh.

National Safety Council, 1121 Spring Lake Dr., Itasca, IL 60143-3201. 800-621-7619; www.nsc.org.

National Toxicology Program, Department of Health and Human Services, P.O. Box 12233, MD A3-01, Research Triangle Park, NC 27709. 919-541-0530; ntp-server.niehs.nih.gov.

Occupational Safety & Health Administration, 200 Constitution Ave., N.W., Washington, DC 20210. 800-321-6742; www.osha.gov.

U.S. Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Ave., N.W., Washington, DC 20460. 202-272-0167; www.epa.gov.

U.S. Government Printing Office, 732 North Capitol St., N.W., Washington, DC 20401. 202-512-0000; www.access.gpo.gov.

U.S. Nuclear Regulatory Commission, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852-2738. 800-368-5642; www.nrc.gov.

Electronic Media

Chemical toxicity, as well as much regulatory and emergency response information, can be handled in electronic files. Until the mid-1980s, electronic files were most commonly available as online databases to which access was measured and sold by database vendors based on the number of hours connected. This is still a good option in many circumstances, particularly for bibliographic files. Database users need computer terminals and modems as well as vendor-assigned passwords to access these databases. Front-end software, when installed on a personal computer, will make searching the electronic files easier. Nevertheless, attendance at a user-training workshop offered by the database vendor and the willingness to maintain the appropriate documentation are also recommended. As an alternative, almost all academic and many public libraries offer database search services. Finally, the database vendors themselves will perform searches for customers.

In the past several years, more and more electronic databases have become available as CD-ROM (compact disc read-only memory) products. In the most commonly available format, the discs store approximately 550 MB of information. The services are usually sold by subscription with at least quarterly updates. For the

CD-ROM discs to be used, a personal computer with a monitor and (optional) printer and a CD-ROM player are required. CD-ROM products should be considered when there is potentially high use of the data files, when it is desirable not to depend on telecommunication links, or when the files themselves (such as collections of MSDSs) are well-adapted to the format. Perhaps they should not be used when it is essential to have the most current information. In this case, access to online databases may be better. However, online databases will only be as current as the updating policies of the vendors, and many files are updated as rarely as quarterly.

Many databases are available in both online and CD-ROM formats or even additional ones such as floppy disks or magnetic tapes. In addition to the many collections of MSDSs, some of the potentially more useful databases are the following:

- Chemical Hazards Response Information System (CHRIS). U.S. Coast Guard hazard response.
- CHEMLIST. Regulatory activities such as premanufacture notices and EPA rule making.
- Hazardous Substances Data Bank (HSDB). Reviewed data on environmental and regulatory issues as well as toxicological information.
- NIOSHITC. searchable bibliographic database of occupational safety and health publications, documents, grant reports, and other communication products supported in whole or in part by the National Institute for Occupational Safety and Health (NIOSH).
- Oil and Hazardous Material Technical Assistance Data System (OHMTADS). Information from EPA.
- Registry of Toxic Effects of Chemical Substances (RTECS). Acute and chronic toxicity information.
- Toxicology Literature Online (TOXLINE). Bibliographic database covering the toxicological and physiological effects of drugs and other chemicals.

APPENDIX II

Occupational Safety & Health Administration Regional Offices

Region 1

(CT, #* MA, ME, NH, RI, VT*)
JFK Federal Building, Room E340
Boston, MA 02203
Telephone: 617-565-9860

Region 2

(NJ, # NY, # Puerto Rico, *
Virgin Islands#)
201 Varick St., Room 670
New York, NY 10014
Telephone: 212-337-2378

Region 3

(DC, DE, MD, * PA, VA, * WV)
The Curtis Center, Suite 740 West
170 South Independence Mall West
Philadelphia, PA 19106-3309
Telephone: 215-861-4900

Region 4

(AL, FL, GA, KY, * MS, NC, *
SC, * TN*)
61 Forsyth St., S.W.
Atlanta, GA 30303
Telephone: 404-562-2300

Region 5

(IL, IN, * MI, * MN, * OH, WI)
230 South Dearborn St., Room 3244
Chicago, IL 60604
Telephone: 312-353-2220

Region 6

(AR, LA, NM, * OK, TX)
525 Griffin St., Room 602
Dallas, TX 75202
Telephone: 972-850-4145

Region 7

(IA, * KS, MO, NE)
City Center Square
1100 Main St., Suite 800
Kansas City, MO 64105
Telephone: 816-426-5861

Region 8

(CO, MT, ND, SD, UT, * WY*)
1999 Broadway, Suite 1690
Denver, CO 80202
Telephone: 720-264-6550

Region 9+

(AZ, * CA, * Guam, HI, * NV*)
71 Stevenson St., Room 420
San Francisco, CA 94105
Telephone: 415-975-4310

Region 10

(AK, * ID, OR, * WA*)
1111 Third Ave., Suite 715
Seattle, WA 98101-3212
Telephone: 206-553-5930

CT, NJ, NY, and Virgin Islands plans cover public sector (state and local government) employment only.

* State with approved state plan.

+ Region 9 has three types of offices: (1) state, (2) federal, and (3) consultation project offices.

APPENDIX III

Environmental Protection Agency Regional Offices

Region 1

(CT, MA, ME, NH, RI, VT)
1 Congress St., Suite 1100
Boston, MA 02114-2023
www.epa.gov/region1
Telephone: 617-918-1111
Toll-free: 888-372-7341
Fax: 617-918-0101

Region 2

(NJ, NY, Puerto Rico, Virgin Islands)
290 Broadway
New York, NY 10007-1866
www.epa.gov/region2
Telephone: 212-637-3660
Fax: 212-637-3526
Fax: 913-551-7066

Region 3

(DC, DE, MD, PA, VA, WV)
1650 Arch St. (3PM52)
Philadelphia, PA 19103-2029
www.epa.gov/region3
Telephone: 215-814-5000
Toll-free: 800-438-2474
Fax: 215-814-5103
E-mail: r3public@epa.gov

Region 4

(AL, FL, GA, KY, MS, NC, SC, TN)
Sam Nunn Atlanta Federal Center
61 Forsyth St., S.W.
Atlanta, GA 30303-8960
www.epa.gov/region4
Telephone: 404-562-9900
Toll-free: 800-241-1754
Fax: 404-562-8174

Region 5

(IL, IN, MI, MN, OH, WI)
77 West Jackson Blvd.
Chicago, IL 60604
www.epa.gov/region5
Telephone: 312-353-2000
Toll-free: 800-621-8431
Fax: 206-553-0149

Region 6

(AR, LA, NM, OK, TX)
1445 Ross Ave., Suite 1200
Dallas, TX 75202
www.epa.gov/region6
Telephone: 214-665-6444
Toll-free: 800-887-6063
Fax: 214-665-7113

Region 7

(IA, KS, MO, NE)
901 North 5th St.
Kansas City, KS 66101
www.epa.gov/region7
Telephone: 913-551-7003
Toll-free: 800-223-0425

Region 8

(CO, MT, ND, SD, UT, WY)
1595 Wynkoop St., 80C-EISC
Denver, CO 80202-1129
www.epa.gov/region8
Telephone: 303-312-6312
Toll-free: 800-227-8917
Fax: 303-312-6961
E-mail: r8eisc@epa.gov

Region 9

(AZ, CA, HI, NV)
75 Hawthorne St.
San Francisco, CA 94105
www.epa.gov/region9
Telephone: 415-947-8000
Toll-free: 866-EPA-WEST
Fax: 415-947-3553
E-mail: r9.info@epa.gov

Region 10

(AK, ID, OR, WA)
1200 Sixth Ave.
Seattle, WA 98101
www.epa.gov/region10
Telephone: 206-553-1200
Toll-free: 800-424-4372

APPENDIX IV

Checklist of Minimum Requirements for Chemical Laboratory and Workplace Design

For additional information, refer to *Guidelines for Laboratory Design: Health and Safety Considerations, third edition, and Improving Safety in the Chemical Laboratory: A Practical Guide, second edition.*

- At least two exits are in place, with doors opening outward, preferably into an offset. (Direct openings partially block passages and corridors.) Exits should be at opposite ends of the facility and easily accessible from all locations.
- Aisles are at least 4 feet wide.
- Laboratory chemical hoods are sufficient and have adequate ventilation. Employees should be able to use laboratory chemical hoods without crowding. The hoods should be located so that they are not near desks or areas in which employees congregate.
- Desks are located so that spills or other accidents do not endanger employees sitting at the desks.
- Safety showers and eyewash fountains are at easily accessible locations for all employees. These locations should not tempt employees to restrict access to showers or eyewashes by placing boxes in front of the emergency facilities.
- Appropriate fire extinguishers are dispersed throughout the laboratory and near the exits.
- Grounded (three-prong) electrical receptacles are sufficient and make extension cords unnecessary. No cords should be on the floor or across aisles.
- Provision has been made for gas cylinders to be located out of the main traffic flow and properly strapped or chained.
- Tops of benches and tables are impervious to chemical spills.
- Adequate storage space is available for flammables.
- The shelving units or cabinets are sufficient. No chemicals or supplies should be stored on the floor.
- Lighting is adequate.
- Pipes and conduits have been installed so as not to block aisles. They should allow for adequate headspace.
- New construction and renovation of existing facilities should meet the ADA Accessibility Guidelines.

APPENDIX V

Properties of Protective Clothing Materials*

For the most current information in this area, consult the NIOSH protective equipment program.

Material	Strength	Chemical Resistance	Flammability	Static Properties	Comfort	Uses
Cotton	Fairly durable	Degraded by acids; binds some chemicals	Requires special treatment for flame-retardancy	No static problems	Comfortable, lightweight	Lab coats
Modacrylic	Resistant to rips and tears, but less so than polyamide fibers; abrasion resistant, but less so than nylon or polyester	Resistant to most chemicals and to flame penetration; will not melt or drip; self-extinguishing; rapidly dissipates when source of ignition is removed	In direct flame, fabric shrinks	Has antistatic properties	Comfortable, soft, and resilient; easy to clean and has soil-release properties	Lab coats
Nylon	Exceptionally strong and abrasion resistant	Not water absorbant	Melts when heated; requires flame-retardant	Static buildup possible; requires antistatic agent	Lightweight	Lab coats
Plastic	Usually reinforced at points of strain; will stick together, peel, crack, or stiffen	Resistant to corrosive chemicals	Can be ignited by flammable solvents and others in event of static discharge	Accumulates considerable charge of static electricity	Lightweight	Aprons, sleeve protectors, boots
Polyolefin	Resistant to	Excellent chemical resistance; resistant to rips and tears	High melting point; low binding for chemicals	Good point; flame resistant	Lightweight; static dissociation	Bouffant caps good permeability; limited moisture absorption; may be uncomfortable if the wearer is perspiring
Polypropylene	Strong	Resistant to most chemicals; oxygen and light sensitive	Low melting point; requires flame-retardant	Static buildup; requires antistatic agent	Lightweight	Aprons
Rayon	Fairly durable	Degraded by acids; binds some chemicals				Lab coats

*Based on manufacturers' claims

APPENDIX VI

Incompatible Chemicals

The following list is to be used only as a guide. Specific incompatibilities are listed in the MSDSs. You may also wish to consult *Bretherick's Handbook of Reactive Chemical Hazards*.

Chemical	Incompatible With
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetone	Concentrated nitric and sulfuric acid mixtures
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali and alkaline earth	Water, carbon tetrachloride or other metals (such as powdered chlorinated hydrocarbons, carbon dioxide, aluminum or magnesium, halogens calcium, lithium, sodium, potassium)
Ammonia (anhydrous)	Mercury (e.g., in manometers), chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
Ammonium nitrate	Acids, powdered metals, flammable liquids, chlorates, nitrites, sulfur, finely divided organic combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent
Azides	Acids
Bromine	See Chlorine
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents
Chlorates	Ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials

Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals, turpentine
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Chromic acid and chromium	Acetic acid, naphthalene, camphor, glycerol, trioxide alcohol, flammable liquids in general
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids (organic or inorganic)
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Fluorine	All other chemicals
Hydrocarbons (such as butane,	Fluorine, chlorine, bromine, chromic acid, propane, benzene) sodium peroxide
Hydrocyanic acid	Nitric acid, alkali
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous)
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitrates	Acids
Nitric acid (concentrated)	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids and gases, copper, brass, any heavy metals
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury
Oxygen	Oils; grease; hydrogen; flammable liquids, solids, and gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils

Peroxides, organic	Acids (organic or mineral)
Phosphorus (white)	Air, oxygen, alkalies, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids
Potassium perchlorate <i>See also Chlorates</i>	Sulfuric and other acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Potassium chlorate; potassium perchlorate; potassium permanganate; similar compounds of light metals, such as sodium, lithium
Tellurides	Reducing agents

APPENDIX VII

Facilities Safety and Housekeeping Inspection Report

This listing is not intended to be complete. Use it as a guide when preparing a similar list for your use that applies to your situation.

Facility No. _____ Bldg. _____

Areas of Inspection	Comments and Recommendations*
1. Bench tops	_____
2. Areas under sinks	_____
3. Cabinets, drawers, shelves (chemicals properly stored)	_____
4. Hoods and other ventilation	_____
5. Aisles	_____
6. Window ledges	_____
7. Walls and floors	_____
8. Chairs, stools, upholstery, casters	_____
9. Safety glasses, face shields, protective clothing	_____
10. Fire extinguishers	_____
11. Compressed gas cylinders	_____
12. Broken glassware: Destroy? Repair?	_____
13. "No Smoking" and "No Eating" signs	_____
14. Tubing and hoses: Condition? Proper use?	_____
15. Guards on moving equipment	_____
16. Interlocks	_____
17. Condition of equipment	_____
18. Refrigerators	_____
19. Electric cords, other wiring	_____
20. Eyewashes and safety showers	_____
21. Storage of peroxide-forming chemicals	_____
22. Storage of chemicals in work area	_____
23. Storage of chemicals in storage area	_____
24. Evaluation of amount of supplies and equipment	_____
25. Laboratory desks, bookshelves	_____
26. Office housekeeping	_____
27. Other	_____

Actions taken and other recommendations: _____

Inspection made by _____ Date: _____

*Please use additional sheets if necessary.

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